WINTER

Diamond tools

for machining precision optical glass, spectacle lenses and technical glass components

SAINT-GOBAIN
ABRASIVES

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Certified to DIN EN ISO 14001 Certificate No. EM-2129 HH

Certified to DIN EN ISO 9001 Certificate No. QS-453 HH

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Preface

WINTER diamond tools for manufacturing optical and technical glass components are well known throughout the world for their quality and long life.

The experience from decades of cooperation with industry called for constant improvements and expansions in the range of tools.

The present catalogue draws on this experience and gives useful advice on the application and selection of diamond tools for glass machining.

A combination of knowledge and care is required to improve machining results while at the same time keeping costs down. The recommendations given should be regarded purely as examples, since not all details can be included in a catalogue - in view of the wide range of applications there are a large number of possible solutions.

Our specialist engineers will be happy to advise you in the use of WINTER tools, and will help you to find the best solution for your specific application. The WINTER applications engineer is the right man to consult, for optimization of existing work processes or development of new applications.

Diamond tools

Milling tools for precision optics, spectacle lenses and technical components

Precision optics covers all kinds of optical components for imaging systems such as objective lenses, microscope components, telescope mirrors, laser systems, nuclear engineering, data processing and many other applications. Spectacle lens manufacturing is an area within precision optics.

Technical components covers all other components, some of which require extreme accuracy with techniques similar to those used in precision optical machining.

The steps in machining with diamond tools are:

Rough milling - fine milling - cutting off

for spherical, aspherical and flat surfaces.

Fine milling with pellet tools

Pellets are metal or resin bond diamond tools, largely cylindrical in shape, in the diameter range 4...10...(15)mm; before application, they have to be bonded or brazed into position. Their surface geometry has to be adjusted to the desired shape, within the specified tolerances, by grinding them over before using them for machining.

The introduction of pellet tools improved the geometric accuracy and thus the life of fine milling tools so much that loose abrasive for lapping (not to be confused with polishing agents) was replaced, and considerable progress was made in rationalisation and automation of processes.

Definitions of optical terms

Spherical	Used to describe all lenses which have a spherical surface at least on one side, defined by a radius of curvature.
Aspherical	Used to describe surfaces which are neither spherical nor flat, e.g. a parabolic surface, or special non-spherical shapes for spectacle lenses.
Toric	Used to describe a surface having two curves superposed on one another with a certain angle between them, i.e. the "base curve". This is comparable with the surface of a car tyre - the base curve corresponds to the outer diameter of the tyre, while the cylindrical curve corresponds to the curve across the tread of the tyre.
Diopter	This is the unit of strength or focal power of a lens. The diopter is the international standard unit of power. One diopter (1D) is equivalent to the reciprocal of the focal length (B) in metres: 1D = 1 m, 10D = 0.1 m =100 mm.

The formula for calculation of the radius of curvatureis:

Radius of curvature $R = (n_d - 1) : B$

where n_d is the refractive index of the type of glass used.

Example: n_d = 1.523 for crown glass BK7 (Schott), desired power D = 3.

B = 1 : 3 = 0.333 mm.

Thus radius of curvature R = (1.523 - 1) : 0.333 = 1.5705 m.

Ordering data

Ordering data

The following data must be given when ordering diamond tools:

- Shape of required tool
- Dimensions including bore size/mounting (machine connection)
- Grit size(s)
- Bond
- Concentration

} together known as the specification

Ordering examples are given with all tables in this catalogue, so that you can check for yourself whether your data are complete.

Diamond tool shape

We recommend that specification should always take account of the following key factors:

- For reasons of cost-effectiveness, it should be possible to use up the grinding layer as completely as possible.
- La-yer depth and layer volume should be specified as large as possible (if necessary after testing), because the manufacturing cost is virtually unchanged for a greater depth of layer, so that twice the layer depth costs less than twice the price.
- Wheel diameter should be specified as large as possible, in order to improve the cost ratio (manufacturing cost to layer volume cost).

Diamond grit sizes

International Standardization of grit sizes					**WINTER**	
Sieve grit designations					**Micron powder designations *)**	
Diamond FEPA Standard **Winter code** narrow	narrow	**Diamond** US Standard **ASTM-E-11-70** narrow	narrow	Nominal mesh width to ISO 6106 **DIN 848 Pt. 1, 1980** µm	**Diamond WINTER** code	For comparison: Grit size µm
D601)**	**D602**)**	30/35	**30/40**	600/500	**D25**	32-52
D501)**		35/40		500/425	**D20B**	30-40
D251		60/70		250/212	**D20A**	25-30
D213		70/80		212/180	**D15**	10-25
D181		80/100		180/150	**D15C**	20-25
D151		100/120		150/125	**D15B**	15-20
D126		120/140		125/106	**D15A**	10-15
D107		140/170		106/90	**D7**	5-10
D91		170/200		90/75	**D3**	2-5
D76		200/230		75/63	*) Similar FEPA standard exists with designations M 63...M 1.0	
D64		230/270		63/53	**) Only for electroplated tools	
D54		270/325		53/45		
D46		325/400		45/38	FEPA= Fédération Européenne des Fabricants de Produits Abrasifs.	

The grit size table shows the diamond grit sieve sizes, which have the same specifications in DIN, ISO and FEPA standards; micron sizes are supplied under WINTER micron powder designations.

Please note that larger grit sizes permit higher material removal rate Q_w in cm^3/min; at the same time tool life is longer (grinding ratio G in cm^3/cm^3), but the generated workpiece surface is rougher. The following rule should be applied for specification of grit size: as coarse as possible, as fine as necessary.

Ordering data

Tabular overview of usual bonds

Glass machining is done almost exclusively with metal bond diamond tools. Resin bond tools are used only for polishing, e.g. for progressive multifocals or for superfinishing optically contacted prisms, and for slitting (cutting off) technical glass components.

Bond group	Bond name	Wear hardness	Application recommendations	Tool type
Metal or bronze bond (grinding wheels)	BZ 488 BZ 486 BZ 457 BZ 444	↑	For profiled tools	Grinding wheels Bevelling wheels Cutting disks (restricted range of bonds)
	BZ 387 BZ 366 BZ 335 BZ 309	↑	Universal bond	
	BZ 560 ST 5314		For large contact surfaces, universal application on toric surfaces	Cup wheels
Electroplated metal bond	G 825		For machining plastic glass	Cup wheels
Metal or bronze bond (pellets)	BT 246 BZ 488 BZ 486 BZ 444 BZ 428 BZ 387 BZ 335 BZ 303 BZ 5017	↑	Universal for spectacle lenses Universal for harder glass types Universal for softer glass types For soft flint glass types	Pellets
Resin bond (pellets)	K-plus 1001Y SP 2012 SP 2013		For grit sizes < D7 For optically contacted prisms For toric and aspherical surfaces, for low grinding forces	

Ordering data

Concentration

The concentration indicates the proportion of diamond in the grinding layer (as a percentage by volume).
The concentration code is internationally standardized, as follows:

C100 means 25% by volume diamond content in the grinding layer.
The diamond content in carats (1 ct = 0.2g)
can be calculated from the density of diamond ρ = 3.52 g/cm^3
C 100 = 4.4 ct/cm^3 layer volume.

All other indications are derived from this:
C 25 = 1.10 ct/cm^3 layer volume
C 40 = 1.76 ct/cm^3 “
C 50 = 2.20 ct/cm^3 “
C 75 = 3.30 ct/cm^3 “
C 90 = 3.96 ct/cm^3 “
C135 = 5.94 ct/cm^3 “

Recommendations for specifying concentration can only be given as guidelines, i.e. the concentration is important for efficient operation (to achieve a self-sharpening process). In general, specify low concentration for a small contact surface, high concentration for a large contact surface.

Self-sharpening process

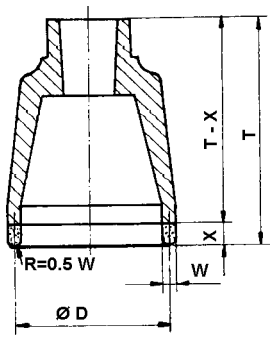
If the specification (grit size + bond + concentration) and the operating parameters are correctly specified, the diamond tool will work efficiently, by means of self-sharpening. This gives optimal economic and technical performance, i.e. low cost and fulfilment of the requirements for tolerance, surface finish and surface integrity. If the self-sharpening process is not working properly, this may be corrected by appropriate changes in specification of the parameters mentioned above (see also Tables on pages 33 and 37). Or to put it another way, the right bond is not the bond with the **lowest** wear rate, but the bond with the **correct** wear rate. Similary, a high diamond concentration is no guarantee for an optimal grinding result. The right specification is one which permits the self-sharpening process, i.e. continuous efficient operation throughout the life of the tool.

WINTER
diamond tools

WINTER: **2F2**
FEPA: **2F2**
DIN: **58741**

Cup wheels for spherical and toric surfaces

2F2



Order designation									Remarks
Shape	D	W	X	T-X	A	Grit size	Bond	Con-cen-tration	
2F2	3	1	6						Ø 3...10
2F2	4	2	6						without radius
2F2	5	2	4-6-10						
2F2	6	2	4-6-10						
2F2	7	2	4-6-10						
2F2	8	2	4-6-10						
2F2	9	2	4-6-10						
2F2	10	2	4-6-10						
2F2	11	2,5	4-6-10						R = 1.25 mm
2F2	12	2,5	4-6-10						
2F2	12,5	2,5	4-6-10						
2F2	14	2,5	4-6-10						
2F2	16	2,5	4-6-10						
2F2	18	2,5	4-6-10						
2F2	20	2,5	4-6-10						
2F2	22	3	4-6-10						R = 1.5 mm
2F2	25	3	4-6-10						
2F2	28	3	4-6-10						
2F2	30	3	4-6-10						
2F2	32	3	4-6-10						
2F2	35	3	4-6-10						
2F2	36	3	4-6-10						
2F2	40	3	4-6-10						
2F2	45	3	4-6-10						
2F2	50	3	4-6-10						
2F2	50	4	4-6-10						R = 2 mm
2F2	55	4	4-6-10						
2F2	56	4	4-6-10						
2F2	60	4	4-6-10						
2F2	63	4	4-6-10						
2F2	70	4	4-6-10						
2F2	71	4	4-6-10						
2F2	75	4	4-6-10						
2F2	80	4	4-6-10						
2F2	90	4	4-6-10						
2F2	100	5	4-6-10						R = 2.5 mm
2F2	110	5	4-6-10						
2F2	125	5	4-6-10						

Other dimensions on request
T-X = Specify core length when ordering. If no indication = standard length.
A = Specify machine connection when ordering (see Tables from page 12 onwards)

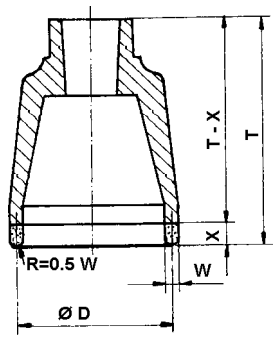
Ordering example: **2F2-20-2.5-10-50-L1 / D126 / BZ486 / C50**
(L1 = Connection for LOH RF1 or DAMA FS100)

WINTER
diamond tools

WINTER: 2F2
FEPA: 2F2
DIN: 58741

Cup wheels for spherical and toric surfaces

2F2



Order designation									Remarks
Shape	D	W	X	T-X	A	Grit size	Bond	Con-cen-tration	
2F2	140	5	4-6-10						R = 2.5 mm
2F2	160	5	4-6-10						
2F2	180	5	4-6-10						
2F2	200	5	4-6-10						
2F2	225	5	4-6-10						
2F2	240	5	4-6-10						
2F2	250	5	4-6-10						

Other dimensions on request
T-X = Specify core length when ordering. If no indication = standard length.
A = Specify machine connection when ordering (see Tables from page 12 onwards)

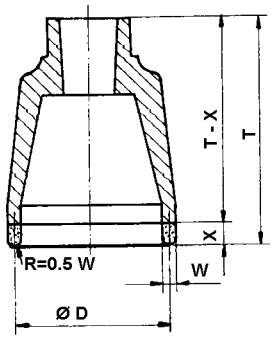
Ordering example: **2F2-200-5-6-50-M22K / D151 / BZ486 / C50**
(M22K = connection for LOH RF3 and BOTHNER B15...B29)

WINTER
diamond tools

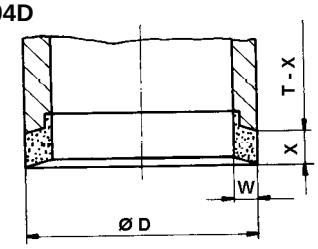
WINTER: 2F2/04D
04C/1S04B
FEPA: 2F2

Cup wheels for toric surfaces on special machines

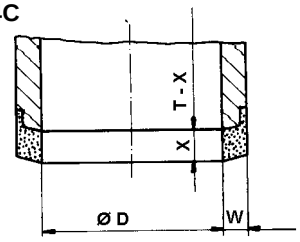
2F2



04D



04C



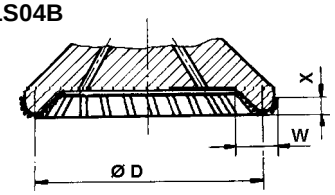
Order designation (sintered version)									
Shape	D	W	X	T-X	A	Grit size	Bond	Con-cen-tration	Remarks
2F2	64	6	12	62	K8				AUTOFLOW
2F2	76	6	12	62	K8				for cc and
2F2	86	6	12	62	K8				cx surfaces
2F2	92	6	12	62	K8				
2F2	82.5	6.5	12	80	K6				COBURN for cc and cx surfaces
04D	60	6.5	12	66	L4				LOH
04D	70	6.5	12	66	L4				for cc surfaces
04D	80	6.5	12	66	L4				(concave)
04D	90	6.5	12	66	L4				
04C	60	6.5	12	66	L4				LOH
04C	70	6.5	12	66	L4				for cx surfaces
04C	80	6.5	12	66	L4				(convex)
04C	90	6.5	12	66	L4				
04C	100	6.5	12	66	L4				
2F2	70	10	10	50	W25K				OPTIBEL for cc and
2F2	80	5	8	66	W25K				cx surfaces

Other dimensions on request

Ordering example: **2F2-86-6-12-62-K8 / D181 / ST5314 / C25 (for cc and cx)***
04D-90-6.5-12-66-L4 / D181 / ST5314 / C25 (for cc)*
04C-90-6.5-12-66-L4 / D181 / ST5314 / C25 (for cx)*

* Standard design without grooves. With grooves: please order 04DN or 04CN.
(N = with grooves, at extra cost)

1S04B



Order designation (electroplated version)									
Shape	D	W	X	T	A	Grit size	Bond	Con-cen-tration	Remarks
1S04B	65	14	5	75	L4	D501	G825	S33	for cc and cx
1S04B	80	14	5	75	L4				surfaces
1S04B	100	14	5	75	L4				Plastic lenses

Other dimensions on request

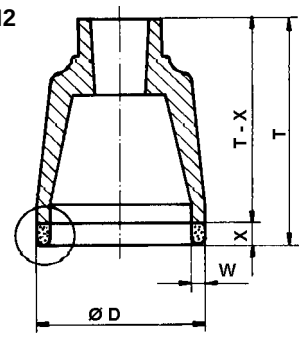
T = Total length, please specify when ordering

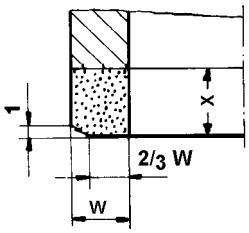
Ordering example: **1S04B-100-14-5-75-L4 / D501 / G825 / S33**
for LOH Toromatic CNC

WINTER: 2M2
FEPA: 2M2

Cup wheels for surface milling (flats, prisms)

2M2





Order designation									Remarks
Shape	D	W	X	T-X	A	Grit size	Bond	Con-cen-tration	
2M2	40	5	4-6-10						
2M2	45	5	4-6-10						
2M2	55	5	4-6-10						
2M2	60	5	4-6-10						
2M2	65	5	4-6-10						
2M2	75	5	4-6-10						
2M2	85	5	4-6-10						
2M2	105	5	4-6-10						
2M2	125	5	4-6-10						
2M2	155	5	4-6-10						

Other dimensions on request
T-X = Specify core length when ordering. If no indication = standard length.
A = Specify machine connection when ordering (see Tables from page 12 onwards)

Ordering example: **2M2-60-5-10-50-L1 / D126 / BZ335 / C50**
(L1 = Connection for DAMA FS 100 and LOH RF1)

Order designation for LOH automatic prism grinder CNC									Remarks
Shape	D	W	X	T-X	A	Grit size	Bond	Con-cen-tration	
2M2	100	5	5	20	L6				Prisms with straight edges
2M2	100	15	6	19	L6				Prisms with round edges

Other dimensions on request
T-X = Specify core length when ordering. If no indication = standard length.
A = Specify machine connection when ordering (see Tables from page 12 onwards)

Ordering example: **2M2-100-5-5-20-L6 / D91 / BZ560 / C25**
(L6 = Connection for LOH automatic prism grinder)

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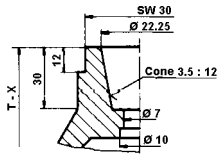
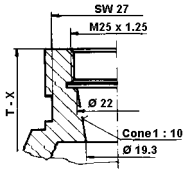
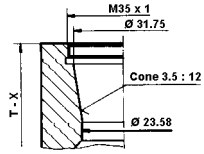
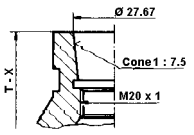
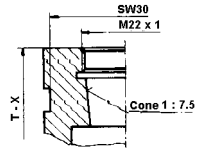
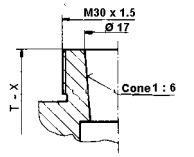
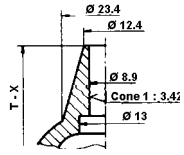
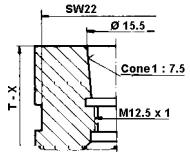
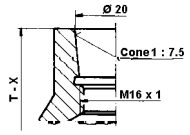
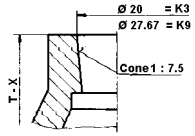
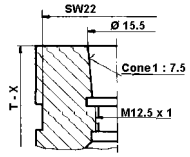
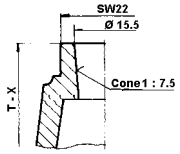
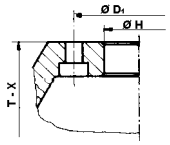
T-X : Core length
A : Machine connection

T-X = Standard length if not specified
A = Please specify when ordering

Machine builder	Machine type	Wheel diameter range mm	**T-X** Core length mm	**A** Machine connection code	Sketches Machine connection	
AUTOFLOW	200		62	K8		K8
	Toric generating: Supermatic MK3 Hyline Radmaster	86 or 92	50	M25K		M25K
Bothner	B 15/80 B 16 B 22/350	40-160 80-315 63-200	94 94 94	M35K / KM20 M35K / KM20 M35K / KM20 optionally		M35K
	B 15/60 B 25 B 26 B 27 B 29	10-160 10-63 10-63 10-63 40-140	62 62 62 62 62/94	M35K M35K M35K / M22K M35K / M22K M35K / M22K optionally		KM20
						M22K
CMV	100 130	40-80 40-80	26 26	M30K M30K		M30K
COBURN	Manumatic 112 AW for toric surfaces		80	K6		K6

T-X : Core length
A : Machine connection

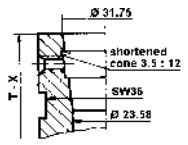
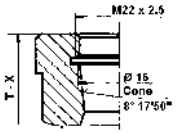
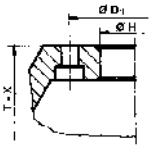
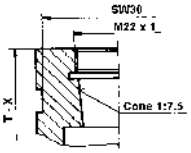
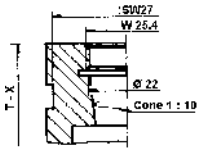
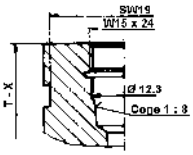
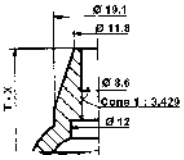
T-X = Standard length if not specified
A = Please specify when ordering

Machine builder	Machine type	Wheel diameter range mm	**T-X** Core length mm	**A** Machine connection code	Sketches Machine connection	
DAMA	FS100 Mikro FS100 (FS19)	≤ 100	50	L1		L1
	FSA80 (FS2) FSA100 FSK200 (FSK150)	≤ 80 ≤ 100 ≤ 200	60	KM16		KM16
	FSA200 FS400	≤ 25	60 85	K3 K9		K3/K9
LOH	RF1	≤ 25	50	L1		L1
	RF1	≤ 60	50	L2		L2
	RF2	60-125 140 160 180-200 225-250 280	54 59 64 69 79 89	L3 L3 L3 L3 L3 L3		L3
	UFMS	150	see RF2	L3	H = 35 mm for Ø ≤ 100 mm H = 35 mm for Ø ≥ 100 mm	

WINTER
diamond tools

T-X : Core length
A : Machine connection

T-X = Standard length if not specified
A = Please specify when ordering

Machine builder	Machine type	Wheel diameter range mm	**T-X** Core length mm	**A** Machine connection code	Sketches Machine connection	
LOH	RXT Toromatic CNC (for toric surfaces)	60-100	66 66	L4 L4		L4
	RFSA SPM100		50	L4		
	SPM35	16-30	36	L5		L5
	SPM200 SPM300	30-140 60-180	39 49	Ø ≤ 50 L4 Ø ≥ 50 L6		L6 H = 28 mm for Ø 56...80 mm H = 35 mm for Ø 90...125 mm H = 50 mm for Ø 140...200mm
	RF1S RF3 UFM	50	50 50 50	M22K M22K M22K		M22K
OPTIBEL	MD / MDM MC / MCM also for toric surfaces		50 50	W25K W25K		W25K
	GMD		33	W15K		W15K
	MTA for toric surfaces					
SHURON	Continental for toric surfaces		80	K7		K7

WINTER: 2F2/2M2
FEPA: 2F2/2M2
Milling with cup wheels
Application notes, results

Technical notes

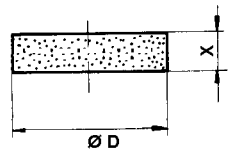
RECOMMENDATIONS		2F2		2M2	2F2-04D-04C
		Spherical surfaces		Flat surfaces	Toric surfaces
Wheel diameter D	mm	One-off production	Series production		
Workpiece diameter D_w	mm	(0.55...0.75) · D_w	(0.52...0.60) · D_w	40....155	100...60
Grit size	FEPA	D25...D91...D191	D91...D181	D46...D151	D181...D213
Bond	Wear hardness	(BZ316) - BZ335 - BZ444 - (BZ486)		BZ335...BZ488	BZ5314
Concentration	C100 = 4.4 ct/cm³	(C25)...C40...C50...(C75, C90)		C50...C75	C25...C35
Cutting speed	m/s	20...30...(50)		20...30...(50)	15...25
Infeed	mm	Roughing: 1/3 of grit size Finishing: 1/10 of grit size		Full depth: 1...3	Full depth: 3...8
Feed rate	mm/min	0.15...5, dependent on n_w			...300
Material removal rate	cm³/min	Roughing: 10...30...100 Finishing: 5...10		10...50 5...10	- 40...120
Workpiece speed	1/min	60...240		-	-
RESULTS					
G-ratio	cm³/cm³	5000...25000 dependent on specification		as 2F2	as 2F2
Life (total lenses)	1	-		-	15000...28000
Specific removal volume	cm³/ct	10000...25000		as 2F2	
Surface finish R_z	µm	4...15		6...15	
		Dependent on grit size, cutting speed, overlap ratio and dwell time			
Tool cost K_w	DM/surface	approx. 0.005		-	appr. 0.03
CUTTING FLUID	Manufacturer	Name		Blend	Type
According to manufacturer's recommendations	Aachener Chemie	AC 3676 AC 4078 AC 6088		2-3%	Fully synthetic Fully synthetic Fully synthetic
	Cincinnati Milacron	Cimplus D14A, Cimcool 400 MSL		Acc. to manufacturer's instr.	Emulsion
	Consulta Chemie	Rondgrind K1, Rondogrind S		Acc. to manufacturer's instr.	Fully synthetic
	Houghton	Glasgrind 456, Glasgrind 721		Acc. to manufacturer's instr.	Emulsion
	LOH	K 80 K 40 K 60		Acc. to manufacturer's instr. 100 %	Fully synthetic Semi-synthetic Containing oil Biodegradable

WINTER
diamond tools

WINTER: 06B...06D

Diamond pellets

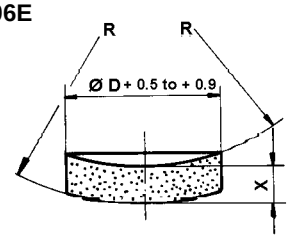
06B



Order designation									
Shape	D	W				Grit size	Bond	Con-cen-tration	Remarks
06B	4	2							
06B	5	2							
06B	6	2							
06B	6	3							
06B	8	2							
06B	8	3							
06B	10	2							
06B	10	3							

Other dimensions on request
Ordering example: 06B-4-2 / D7 / BZ303 / C23 (soft BZ bond)
06B-8-3 / D15A / BZ488 / C35 (hard BZ bond)
06B-10-3 / D15A / SP2013 / C35 (GRESSO resin bond)

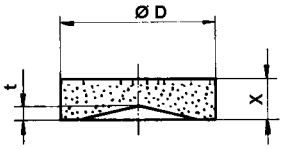
06E



Order designation									
Shape	D	X	R			Grit size	Bond	Con-cen-tration	Remarks
06F	10	2	60						For BZ bonds only: BZ303, BZ335 BZ428, BZ444
06F	10	2	80						
06F	10	3	60						
06F	10	3	80						

Other dimensions on request
Ordering example: 06F-10-3-80 / D15A / BT246 / C35

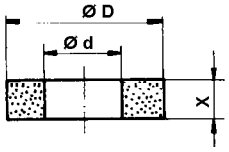
06E



Order designation									
Shape	D	t	X	R	A	Grit size	Bond	Con-cen-tration	Remarks
06E	6	0.2	3						
	10	0.2	3						In BT bond only
06F	10	0.2	3	60					
	10	0.2	3	60					In BT bond only

Other dimensions on request
Ordering example: 06E-10-3-80 / D15A / BT246 / C35
06F-10-3-60 / D15A / BT246 / C35

06D



Order designation									
Shape	D	d	X			Grit size	Bond	Con-cen-tration	Remarks
06B	10	4.5	3						Ring pellets

Other dimensions on request
Ordering example: 06D-10-4.5-3 / D15A / SP2012 / C75

WINTER: 06B...06D

Milling with pellet tools
Application notes, results

Technical notes

Recommendations		Shape 06B-06E-06F-06D (ring)						Remarks
Lens diameter	mm	...20	...40	...60	...80	...120	>120	
Pellet diameter	mm	4	5	6	8	10	10...15	If in doubt, choose smaller pellet diameter
Grit size	WINTER-standard	Precision optics D3...D15A Spectacle lenses D7...D15C Larger grit sizes for cup wheels only						Finer grit sizes permit shorter polishing times and improve shape accuracy
Bond	Wear hardness Grit retention force	Precision optics: BZ and resin bond Spectacle lenses: BT, BZ and resin bond						Wear hardness is an important influence on surface finish and shape accuracy. Hard bond for crown glass, soft bond for flint glass
Concentration	C100 = 4.4 ct / cm³	(C10) C23...C35...C45 (C75)						
Application data								
Layer density	%	35...40	25...30	15...20				The layer thickness and layer pattern influence material removal rate and shape accuracy.
Optical radius	mm	<85	<150	>150				
Workpiece speed	rpm	Limited to 200...2000 due to friction limited by weight						Double the speed gives more than 50% higher material removal rate.
Cutting speed	m/s	3...8						
Contact pressure	N/cm²	15...20						
Feed rate	mm/min	for appr.	D7 0.07	D15A 0.15	D15B 0.45	D15C 0.50		Dependent on workpiece speed and specification.
Material removal rate	cm³/min	appr.	0.1	0.5...10	0.2...0.3	2.5...4.0		Dependent on workpiece speed head angle α and oscillation angle β. These two must be matched to one another.
Results								
Specific removal rate	cm³/ct	155...200	200...300	1000...1500	>2000			Cannot be significantly improved by machine parameters. Dependent on workpiece speed and bond hardness. Very general data, e.g. for spectacle lenses.
Average peak-to-vally height R_z	µm	2...3	2...3	3...4	5...7			
Shape accuracy $\Delta R : \Delta V_w$	µm/cm³	see page 42						
Tool cost K_w	DM/surface	appr. 0.05						
Polishing time	min	The allowance to be removed in the subsequent polishing process determines the polishing time, dependent on grit size of finishing tool.						

WINTER: 06B...06D

Technical notes

Finish grinding with pellet tools
Bonding and breaking in

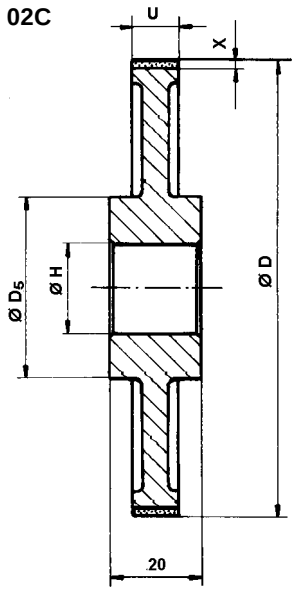
Bonding and breaking in				
Adhesive	Technicoll 8280 (Beiersdorf AG, Hamburg) etc.			
Curing	1 hour at 200° C			
Breaking in	SiC 600...1000 mesh			
Breaking in time	approx. 0.5 hours for small radi (tool diameter 50 mm). approx. 4 hours for flat surfaces (tool diameter 400 mm)			
Solvent	Controx-H 28 (Chem. Fabrik Klüthe KG, Heidelberg) etc.			
Machine for breaking in	1020 C 1090 K, LOH etc.			
Cutting fluid etc.	Manufacturer	Name	Blend	Type
Acc. to manufacturer's recommendation	Aachener Chemie	AC 3676 AC 6088	2 - 3 % 2 - 3 %	Fully synthetic Semi-synthetic
	Cincinnati Milacron	Cimplus/D14A Cimcool/ 400 MSL	Acc. to manufacturer's instructions	Emulsion
	Consulta Chemie	Rondogrind	2 - 3 %	Semi-synthetic
	Houghton Chemie	Glasgrind 456 Glasgrind 721	Acc. to manufactu-rer's instructions	Emulsion
	LOH Optic-Service	K60 K40 K80	100 % Acc. to manufactu-rer's instructions	Oil-containing, biodegradable Semi-synthetic Fully synthetic

WINTER: 02C
DIN: 58742

Bevelling wheels cannot be fitted

Centering wheels without recess

02C



Order designation									Remarks
Shape	D	U	X	H		Grit size	Bond	Con-cen-tration	
02C	100	4	1						D_5 = 40 mm
02C	100	6.3	1						
02C	100	8	1						
02C	100	10	1						
02C	160	5	1						D_5 = 60 mm
02C	160	6.3	1						
02C	160	8	1						
02C	160	10	1						
02C	160	12.5	1						
02C	160	14	1						
02C	160	15	1						
02C	160	16	1						
02C	160	18	1						
02C	160	20	1						
02C	160	25	1						
02C	160	31.5	1						

Other dimensions on request
H = Please specify when ordering

Ordering example: 02C-100-10-1-20 / D46 / BZ335 / C90

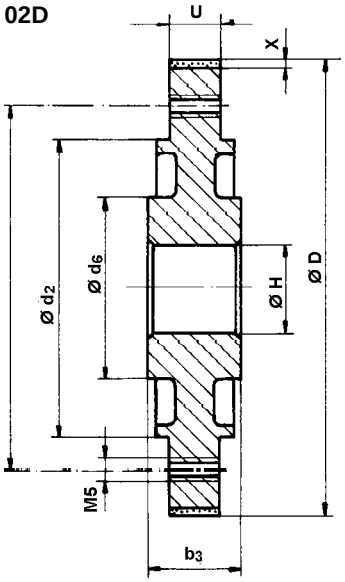
WINTER
diamond tools

WINTER: 02D
DIN: 58742 shape E

Centering wheels with recess

For mounting
bevelling wheels

02D



Order designation									Remarks			
Shape	D	U	X	H		Grit size	Bond	Con-cen-tration	d_2	d_3	d_6	
02D	100	4	1						65	80	40	
02D	100	6.3	1						65	80	40	
02D	100	8	1						65	80	40	
02D	100	10	1						65	80	40	
02D	160	5	1						105	130	60	
02D	160	6.3	1						105	130	60	
02D	160	8	1						105	130	60	
02D	160	10	1						105	130	60	
02D	160	12.5	1						105	130	60	
02D	160	14	1						105	130	60	
02D	160	15	1						105	130	60	
02D	160	16	1						105	130	60	
02D	160	18	1						105	130	60	
02D	160	20	1						105	130	60	
02D	160	25	1						105	130	60	
02D	160	31.5	1						105	130	60	

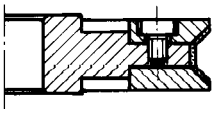
Other dimensions on request
H = Please specify when ordering

Ordering example: 02D-100-8-1-20 / D46 / BZ335 / C90

Ordering example for complete order:
Centering wheel with recess and 2 mounted bevelling wheels (see page 21)
DIN 58742 shape E and 2 pieces shape F, or

02B-100-8-1-1.5-30°-3M-H
(shape-D-U-X-W-α-3 individual tool H)
comprising
02D-100-8-1 / D46 / BZ335 / C90 and 2 pieces
02E-103-1.5-1-30° / D20A / BZ444 / C135

02B

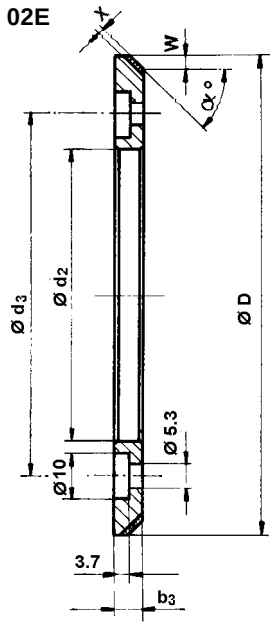


WINTER: 02E
DIN: 58742 Form F

Bevelling wheels (profile wheels)

Fitting centering wheel with recess

02E



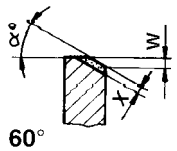
Order designation								Remarks			
Shape	D	W	X	α°	Grit size	Bond	Con-cen-tration	d_2	d_3	T	
02E	101	0.5	1	30-45-60-90				65	80	*	
02E	102	1	1	30-45-60-90				65	80	*	
02E	103	1.5	1	30-45-60-90				65	80	*	
02E	104	2	1	30-45-60-90				65	80	*	
02E	105	2.5	1	30-45-60-90				65	80	*	
02E	106	3	1	30-45-60-90				65	80	*	
02E	161	0.5	1	30-45-60-90				105	130	*	
02E	162	1	1	30-45-60-90				105	130	*	
02E	163	1.5	1	30-45-60-90				105	130	*	
02E	164	2	1	30-45-60-90				105	130	*	
02E	165	2.5	1	30-45-60-90				105	130	*	
02E	166	3	1	30-45-60-90				105	130	*	
02E	167	3.5	1	30-45-60-90				105	130	*	
02E	168	4	1	30-45-60-90				105	130	*	
02E	169	4.5	1	30-45-60-90				105	130	*	
02E	170	5	1	30-45-60-90				105	130	*	

Other dimensions on request
Angle α° = Please specify when ordering.

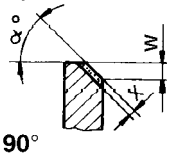
* Dependent on dimensions

Ordering example: **DIN 58742 shape F or**
02E-103-1.5-1-60° / D20A / BZ444 / C125

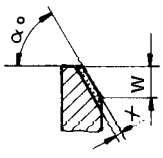
30°



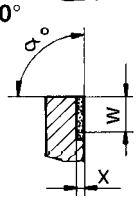
45°



60°



90°

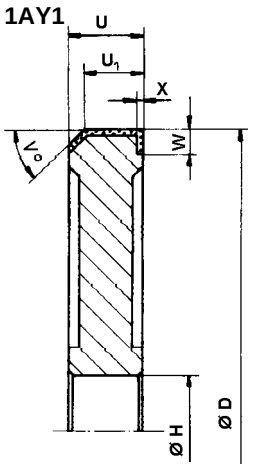


WINTER
diamond tools

WINTER: **1AY1**
FEPA: **1AY1**

Centering and bevelling wheels

Special shapes



Order designation for LOH Centromat CNC											Remarks
Shape	D	U	U_1	X	W	V°	H	Grit size	Bond	Con-cen-tration	
1AY1	160	20	15	1	6	45	30	D64 D20A D20A	BZ444 BZ444 BZ444	C90 C135 C135	Cylindrical part 45° bevel

Other dimensions on request

Ordering example: **1AY1-160-20-15-1-6-45°-30 / D64 / BT246 / C90**

Technical notes

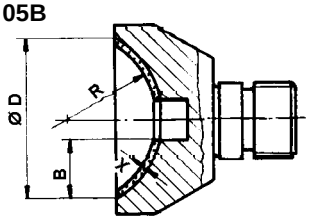
Application notes for centering and bevelling wheels

Recommendations			Centering wheel	Bevelling wheel	
			02C-02D	02E	
Wheel diameter	D	mm	100...160	101...185	
Rim width	U/W	mm	4...31.5	0.5...12.5	
Layer depth	X	mm	1	1	
Grit size	D	FEPA	D64...D46	D25...D20A	
Bond	BZ		BZ335...(BZ444)	BZ444	
Concentration	C	100 = 4.4 ct/cm³	C90	C135	
Cutting speed	v_c	m/s	20...30	20...30	
Infeed	a_e	mm	Continuous to stop	Continuous to stop	
Material removal rate	Q_w	$\frac{mm^3}{min}$	0.5...1	0.01...0.5	
Life:					
G-ratio	G	$\frac{mm^3}{mm^3}$	2000...10000	1000...5000	
Specific removal volume		$\frac{cm^3}{1\ ct}$	3000...10000	3000...10000	
Surface finish	R_z	µm	≤ 5	≤ 5	
Grinding time	t_p	min	4...10	4...10	
Cutting fluid etc.	Manufacturer		Name	Blend	Type
Acc. to manufacturer's instructions	Aachener Chemie		AC 4078 AC 6088	2 - 3 % 2 - 3 %	fully synthetic semi-synthetic
	Cincinnati Milacron		Cimplus M21 Cimcool S4	Acc. to manufacturer's instr.	Emulsion Emulsion
	Consulta Chemie		Rondogrind K1 Rondogrind S	2 - 3 % 2 - 3 %	w. lubricant additive w. lubricant additive
	Houghton Chemie		Glasgrind 721 Glasgrind 456	Acc. to manufacturer's instr.	Oil in water (Emulsion)
	LOH Optic-Service		K40 K43 K60	2 - 3 % 100 % 100 %	semi-synthetic Oil Containing oil Biodegradable

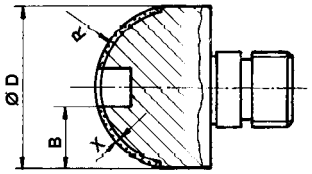
WINTER: 05B, 05C, 05D, 222, 14A1
FEPA: 14A1
DIN: 58723, shape A, B, C

Concave generating tools
Rounding tools

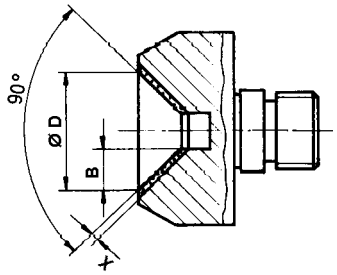
05B



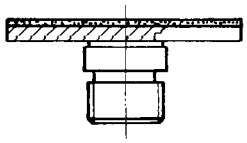
05C



05D



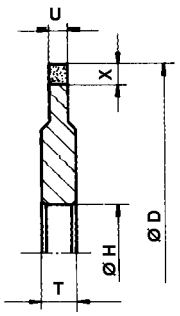
222



Order designation									Remarks
Shape	D	B	X	R or V°	A	Grit size	Bond	Con-cen-tration	
05B (C)	4	*	1-2	*	*				$B \leq \frac{D}{2}$ $R \geq \frac{D}{2}$
05B (C)	5		1-2						
05B (C)	6.3		1-2						
05B (C)	8		1-2						
05B (C)	10		1-2						
05B (C)	12.5		1-2						
05B (C)	16		1-2						
05B (C)	20		1-2						
05B (C)	25		1-2						
05B (C)	32		1-2						
05B (C)	40		1-2						
05B (C)	50		1-2						
05B (C)	63		1-2						
05B (C)	80		1-2						
05B (C)	100		1-2						
05B (C)	125		1-2						
05B (C)	160		1-2						
05B (C)	200		1-2						
05D	9		1-2						
	13		1-2						
	21		1-2						
	34		1-2						
	65		1-2						
222	on request		1-2						

Other dimensions on request *** Please specify when ordering**
A = Please specify machine connection when ordering, see Tables from page 12.
Ordering example: 05B (C)-80-30-1-50-K3 / D15B / BZ335 / C100
222-150-65-1-M22 / D15C / BZ335 / C50

14A1



Order designation, for rounding machine, etc.									Remarks
Shape	D	U	X	H		Grit size	Bond	Con-cen-tration	
14A1	50		4						H = 35 LOH UFM /UFM-S
14A1	60		4						
14A1	75		4						H = 26 DAMA RDM 500 / RDM 125
14A1	100		4						
14A1	125		4						
14A1	150		4						
14A1	150		6						

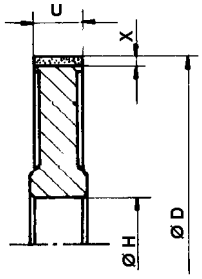
Other dimensions on request **H = Please specify when ordering**

Ordering example: **14A1-100-4-4-26 / D91 / BZ444 / C75 (C90)**
Note : Other usual shapes are FEPA shapes 14L1 and 14F1, grit sizes D64...D126

Edging wheels for spectacle lenses

Mostly used shapes

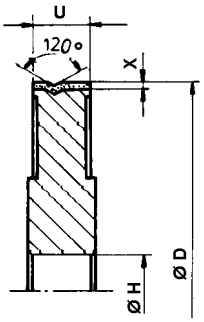
Roughing, straight
1BZ1A1



Order designation								
Shape	D	U	X	H	Grit size	Bond	Con-cen-tration	Machine
1BZ1A1	110	15	1	20	D151	BZ366	C50	
1BZ1A1	110	15	1.6	20	D151	BZ366	C50	
1BZ1A1	110	15	2	20	D151	BZ366	C50	
1BZ1A1	155	15	1	20	D151	BZ366	C50	
1BZ1A1	120	15	1	20	D151	BZ366	C50	
1BZ1A1	165	18	1	30	D151	BZ366	C50	

Other dimensions on request
Ordering example: 1BZ1A1-110-15-1-20 / D151 / BZ366 / C50

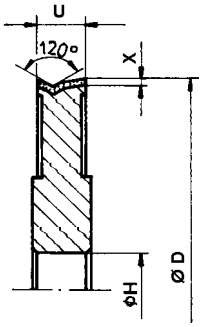
Flach-V-Facette
3BZ700



Order designation								
Shape	D	U	X	H	Grit size	Bond	Con-cen-tration	Machine
3BZ700	110	18	1	20	D46	BZ366	C50	
3BZ700	110	18	1.6	20	D46	BZ366	C50	
1BZ700	155	20	1	20	D46	BZ366	C50	

Other dimensions on request
Ordering example: 3BZ700-110-18-1-20 / D46 / BZ366 / C50

Spezial-V-Facette
4BZ700



Order designation								
Shape	D	U	X	H	Grit size	Bond	Con-cen-tration	Machine
4BZ700	110	15	1	20	D46/25	BZ366	C50	
2BZ700	110	15	1.6	20	D46/25	BZ366	C50	
3BZ700	110	16	1	20	D46/25	BZ366	C50	
1BZ700	110	16	1	20	D46	BZ366	C50	

Other dimensions on request
Ordering example: 4BZ700-110-15-1-20 / D46/25 / BZ366 / C50

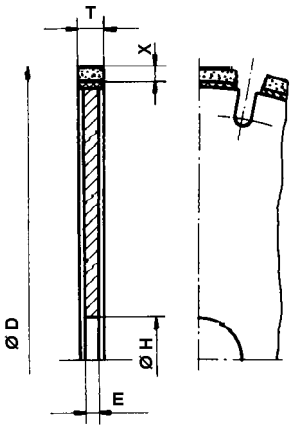
WINTER
diamond tools

WINTER: 34E/1A1R
FEPA: 1A1RSS/ 1A1R

Diamond cutting disks

Extract from WINTER special catalogue

34E

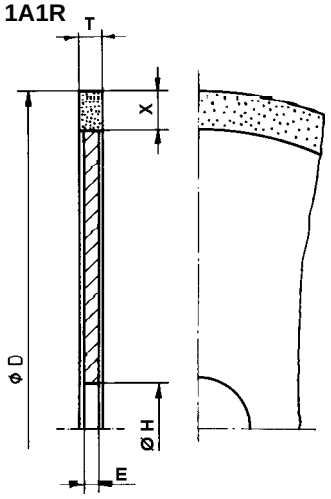


Order designation								
Shape	D	T	X	E	Number of segments	H	Specification	Remarks
34E	400	1.7	5	1.3	28		*	Close-segment design in metal bond (see sketch) for large cutting dephts
34E	420	1.5	5	1.3	30		*	
34E	500	1.7	5	1.3	36		*	
34E	500	2.8	5	2.0	36		*	
34E	700	2.8	5	2.0	50		*	
34E	700	3.2	5	2.0	50		*	
34E	700	3.2	10	2.0	50		*	

Other dimensions on request H = Please specify when ordering
* = Specification on request

Ordering example: 34E-400-1.7-5-1.3-28-H / BZ33904 K2000

1A1R



Order designation									
Shape	D	T	X	E	H	Grit size	Bond	Concentration	Remarks
1A1R	150	0.6...1.8	5-10	0.5...1.6					Design with continuous rim in metal bond
1A1R	250	1.0...1.8	5-10	0.7...1.4					
1A1R	300	1.2...1.8	5-10	0.8...1.4					
1A1R	400	1.5...2.0	5-10	1.1...1.6					

Other dimensions on request H = Please specify when ordering

Ordering example: 1A1R-150-0.6-5-0.5-20 / D64 / BZ309 / C19

Order designation									
Shape	D	T	X	E	H	Grit size	Bond	Concentration	Remarks
1A1R	150	0.6...1.5	7	0.5...1.3					Design with continuous rim in resin bond (see sketch) where there are special requirements for cut quality.
1A1R	300	1.0...1.7	7	0.7...1.4					
1A1R	400	1.2...2.3	7	0.9...1.4					

Other dimensions on request H = Please specify when ordering

Ordering example: 1A1R-300-1.8-5-1.4-H / D91 / K-plus 888RY / C23

WINTER: 34E/1A1R
FEPA: 1A1RSS/ 1A1R

Technical notes

Application notes

Application notes for cutting disks 34E, 1A1R					
Recommendations			BZ 34 E	1A1R	1A1R
			close-segment version for large cutting depths, BZ bond	Continuous rim, universal application, BZ bond	Continuous rim, only for automated machines, resin bond
Wheel diameter	D	mm	200...700	100...400	100...550
Cutting width	T	mm	1.5...3.2	0.5...2.0	0.5...2.0
Layer depth	X	mm	5	5 and 10	5 or 7
Grit size	D	FEPA	D126...D301	(D46)...D64...D181...(D301)	(D46)...D91...D126...(D301)
Bond	BZ K-plus	Wear hardness	BZ... BZ...	BZ309 (< 250) BZ335 and others	K-plus 888RY
Concentration	C	100 = 4.4 ct/ cm³	see page 26	C19...C45	C35...C50
Depth of cut	a_{ges}	mm	...0.35 · D	...0.35 · D	...0.25 · D
Cutting speed	v_c	m/s	20...35...(50)	25...40	30...40
Material removal rate	Z_f	$\frac{cm^2}{min}$	50...100	manual 5...10 machine 10...40	5...20
Feed rate	v_f	mm/min	to be calculated depending on mat. removal rate $Z_f = a_e \cdot v_f$, $v_f = Z_f : a_e$		
Cutting fluid			Öil, oil-in-water solution and water	Mostly water	Öil-in-water, water
Dimensional tolerance		mm	< 0.2	manual < 0.2 machine < 0.05	< 0.03
Surface finish	R_z	µm	25...30	manual < 30 machine < 5...15	5...15

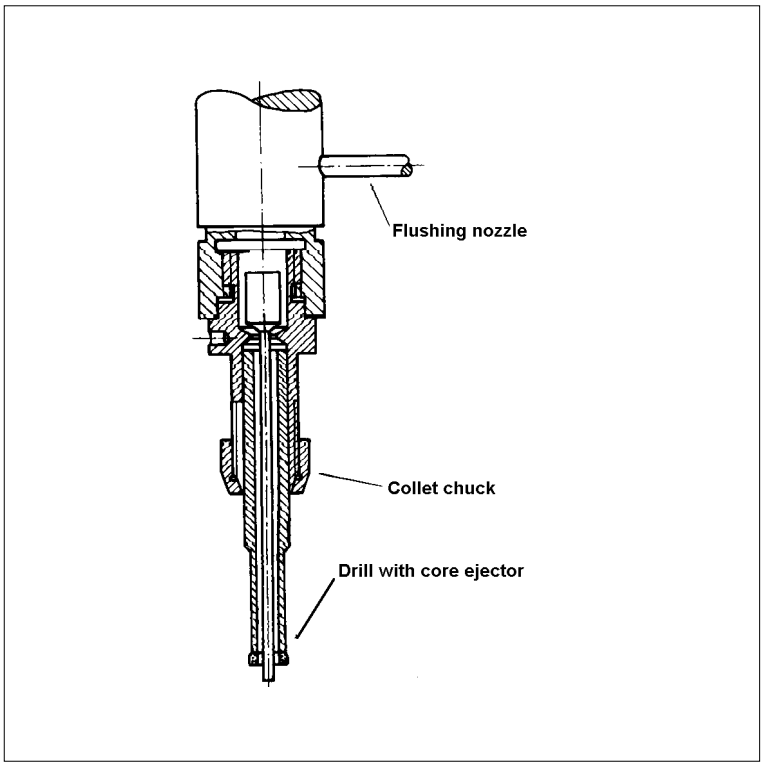
Diamond core drills

Nh drills

Multi-layer Nh drills are suitable for drilling small diameter holes (0.8 to 10 mm) especially in glass and quartz, and within certain limits also in ceramic material. Drilling depth is dependent on the drill diameter, and is between 7 and 22 mm; other dimensions can also be supplied.

Nh drills are supplied with a cylindrical 4 mm shank, fitting the WINTER bench drill TIBO NB4. A collet chuck is required for use of the WINTER flushing nozzle.

For drilling with a standard, fast-running drilling machine, insert the flushing nozzle into the spindle in place of the drill chuck. The flushing nozzle has an internal thread at the bottom for mounting the collet chuck. Switch on water supply before starting to drill, and switch off again only after drilling is finished.



Sharpening: If the drill bit becomes dull, it is advisable to sharpen by drilling into a WINTER Stone No. 2 or 5.

For further information on diamond core drills, please contact:
Ernst WINTER & Sohn GmbH., Hauptstraße 139 a, 55743 Idar-Oberstein, Tel.: +49-6781- 430 87, Fax: +49-6781-411 23, Telex: 42 62 39

General technical notes

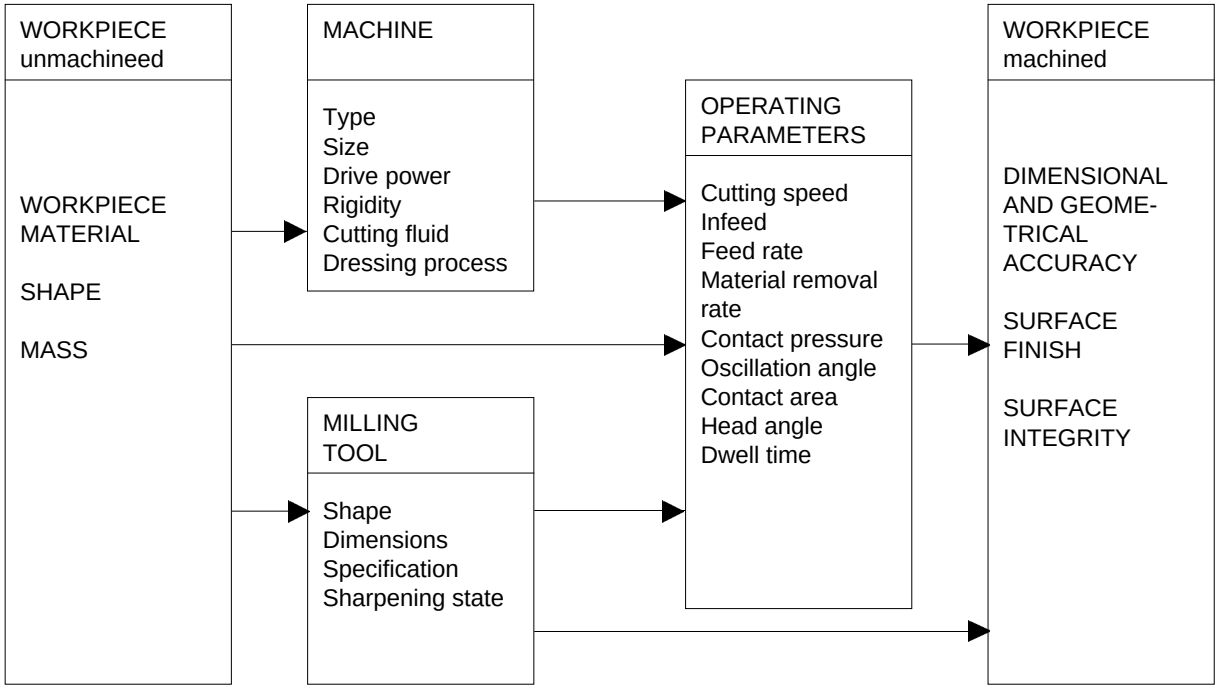
The following diagrams show parameters influencing the machining result.

First the block diagram below shows how the raw blank is transformed into a machined workpiece with the variables:

- the machine
- the milling tool (diamond tool)
- the operating parameters

in such a way as to meet the criteria:

- dimensional and geometrical accuracy
- surface finish
- surface integrity (i.e. minimal surface damage)



Block diagram: Major parameters influencing machining result

The following diagram (page 30) shows a systematic overview of the individual parameters and their effects when quantitative changes are made.

Overview of most important parameters influencing the machining result

General technical notes

Example of practical application

To improve dimensional and geometrical accuracy, the main parameters are the cutting forces F and the grinding ratio G, which in turn are dependent on the eight sub-parameters shown vertically below them, namely:

Cutting speed	Grit size
Material removal rate	Bond wear hardness
Cutting fluid	Concentration
Machining contact area	Sharpening state.

Example: In order to improve the dimensional and geometrical accuracy of the workpiece, check which of the eight sub-parameters indicated above

a) can be changed in the specific case
b) must be changed in order to reduce the grinding force or to get a higher G-ratio.

Assuming the cutting speed is variable and can be increased, the systematic presentation in horizontal direction shows that:

c) the forces are reduced
d) the G-ratio is increased
e) the temperature increases

The changes mentioned under c) and d) are desirable and positive in order to improve geometrical and dimensional accuracy, but the temperature rise (e) can make this speed increase problematic or prohibitive. Check whether the expected temperature increase can be controlled, e.g. by an improvement in cutting fluid supply.

This procedure permits a quick check on which parameter(s) can or must be changed in order to improve geometrical and dimensional accuracy of the workpiece.

Assessment criteria / Influencing factors		Dimension and shape accuracy: Cutting forces F = f(...)	Dimension and shape accuracy: Grinding ratio G = f(...)	Surface quality: Average roughness height R_a R_a = f(...)	Surface quality: Temperature ϑ ϑ = f(...)
Workpiece	Machinability of workpiece material (e.g. hardness and chip form)	F – Machinability	G – Machinability	R_a – Machinability	ϑ – Machinability
Machine and setting parameters	Wheel peripheral speed v_c (m/s)	F – v_c	G – v_c	R_a – v_c	ϑ – v_c
	Material removal rate Q_w (mm³/min)	F – Q_w	G – Q_w	R_a – Q_w	ϑ – Q_w
	Cutting fluid (Oil content)	F – Oil content	G – Oil content	R_a – Oil content	ϑ – Oil content
	Grinding contact (mm²)	F – A_k	G – A_k	R_a – A_k	ϑ – A_k
Grinding wheel	Grit size (µm)	F – Grit size	G – Grit size	R_a – Grit size	ϑ – Grit size
	Bond hardness	F – Bond hardness	G – Bond hardness	R_a – Bond hardness	ϑ – Bond hardness
	Concentration (carat/cm³)	F – Concentration	G – Concentration	R_a – Concentration	ϑ – Concentration
	Active roughness (R_{ts})	F – Acitve roughness	G – Acitve roughness	R_a – Acitve roughness	ϑ – Acitve roughness

Overview of main parameters influencing the machining result

General technical notes

General

Glass is generally subdivided into coloured or colourless glass, transparent or milky. More correctly, it is distinguished by technical terms, into the following:

- Mineral glass, i.e. oxide or silicate and borate glass, and non-oxide, i.e. fluoride glass (chemical classification)
- Organic glass, i.e. polymerized plastics or casting resins (chemical classification)
- Packaging glass, building glass, technical glass, optical glass and special-purpose glass (classification by applications), and
- Sheet glass, hollow glass, block glass, pressed glass, moulded glass blanks (mouldings), extruded glass, foamed glass (classification by production method).

Optical glass

Optical glass is classified as transparent, coloured or filter glass. Coloured and filter glass are the types generally used in precision optics and ophthalmic applications (spectacle lenses). Optical plastics are also used for ophthalmic applications.

Technical glass

Technical glass is not a precisely defined term. All glass materials are used for technical applications, among other things. Selection depends on the specific requirements of the application.

Special-purpose glass

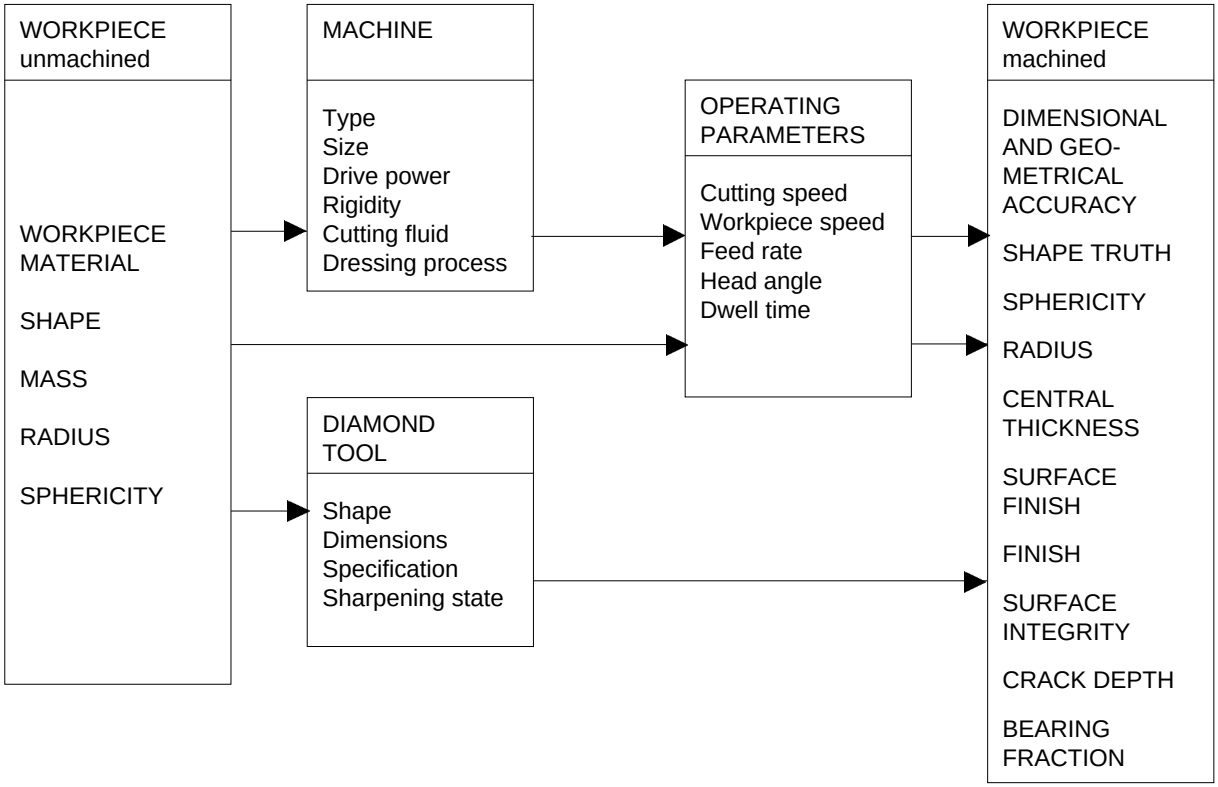
Special-purpose glass covers glass with specifically engineered characteristics, e.g. semi-conductor glass or glass for laser optical systems. Phototropic (or photochromic) glass types are increasingly being used for variable-transmittance spectacle lenses. These glass types adjust automatically (and reversibly) to the light conditions, i.e. they darken when exposed to intense sunlight and fade under dark conditions. This effect is achieved by the inclusion of billions of minute silver halide microcrystals, which react to the ultraviolet radiation of the sun. Glass ceramics are also included in the special glass group. This is a group of substances which combine the major benefits of glass with those of ceramics, and retain a stable shape from -273°C to +600° C.

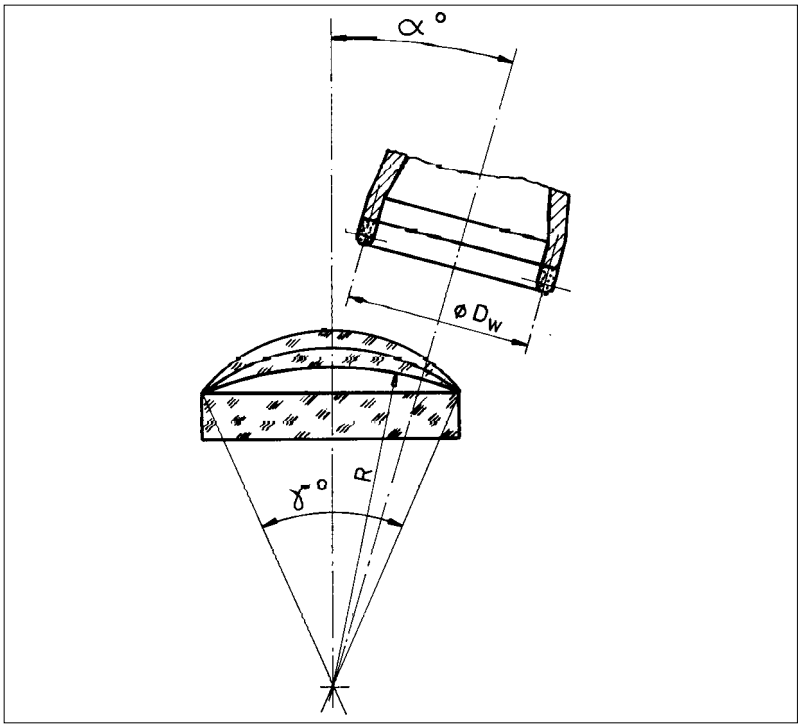
General technical notes

Materials in industry	Material designation acc. to Schott	Density g/cm³	Hardness class kg/mm²	Refractive index n_d	Softening temperature C°	Remarks
Precision optics **Spectacle lenses** General engineering	**Fluor crown glass**					
	FK1 to FK54	2.31 3.18	370 320	1.47069 1.43700	390 403	Material removal properties: splintery chipping of larger workpiece particles at comparatively high machining forces.
	Boron crown glass					
	BK1 to BK10	2.46 2.39	480 490	1.51009 1.49782	547 532	
	Crown glass					
	K3 to K51	2.54 2.47	470 460	1.51823 1.50518	521 521	
	Dense crown glass					
	SK1 to SK55	3.56 3.35	490 550	1.61025 1.62041	650 605	
	Lanthanum crown glass					
	LaKN6 to LaK33	3.80 4.26	460 640	1.64250 1.75398	634 664	
	Flint glass					
	F1 to F15	3.65 3.48	350 390	1.62588 1.60565	432 433	Containing lead oxide, tends to plastification and breakout of large flaky plastic particles, problematic for grinding layer with little chip space. (acc. to König, Steffens, Kleinevoss, AIF Report No. 6242)
	Dense barium flint glass					
	BaSF1 to BaSF64	3.66 3.20	400 540	1.62606 1.70100	493 580	
	Lanthanum flint glass					
	LaF2 to LaFN28	4.34 4.24	480 630	1.74400 1.77314	644 668	
	Dense flint glass					
	SF1 to SFN64	4.46 3.00	340 500	1.71736 1.70585	417 578	
Spectacle lenses	**Phototropic glass**					With halides, also known as photochromic glass.
	Mineral glass Plastic resin (CR39 polymers)	2.41 to 2.5 1.32	480 +/- 30	1.5229 to 1.6000 1.502	510	Trade names: Colormatic, Fotosolar, etc. Organic glass. Trade names: Perfalit-Colormatic etc.
	Plastic glass					Polymerized casting resin (thermosetting), see plastic resin.
	Organic glass	1.32		1.502		
Large optical systems	**Ceramic glass**	2.53	600	1.5430		Schott Name: Zerodur for telescopic mirrors, geometrically stable from -273 to +600° C.
Technical glass	**Quartz glass**	2.2	710	1.4588	Melting point: 1710° C	

General technical notes

Systematic presentation of ways to influence machining results for spherical surfaces.





Basic process for machining spherical lenses, IPT Fraunhofergesellschaft, Aachen, Prof. König.,

Example:

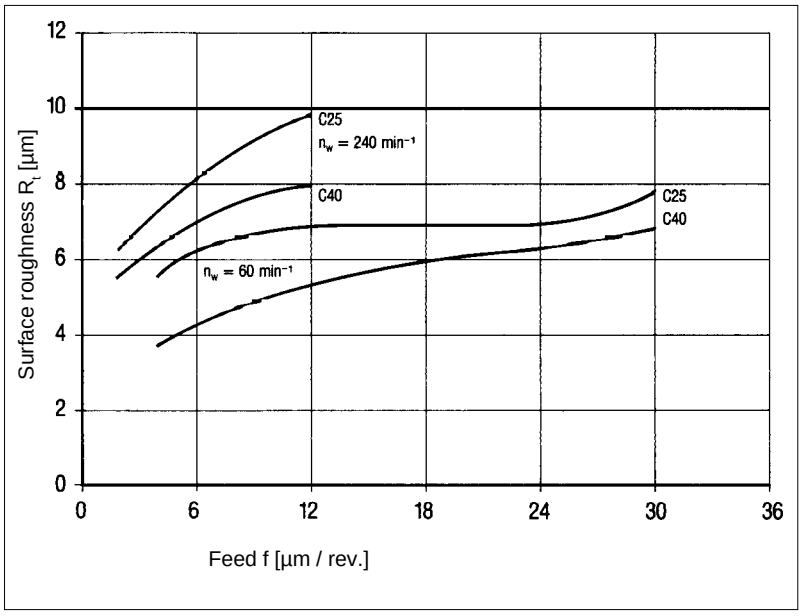
D_w = 55 mm
γ = 2 arc sin D : 2R = 46°
α = 16.2°
R = (n - 1) : diopter

General technical notes

Test results for fine milling of optical glass, pellet tools, acc. to IPT Fraunhofergesellschaft Aachen, Prof. Könik

Test results for machining spherical surfaces:

Fig. 1:	Roughness	R_t	= f	(feed f, workpiece speed n_w, concentration)
Fig. 2:	Roughness	R_t	= f	(feed f, workpiece speed n_w, grit sizes)
Fig. 3:	Spindle drive power	P_s	= f	(material removal rate Q_w, concentration)
Fig. 4:	Spindle drive power	P_s	= f	(grit size, cutting speed v_c)
Fig. 5:	G-ratio	G	= f	(material removal rate V_w, material)



Workpiece: Lens diameter 65 mm
Radius of curvature
R = 150 mm
Material BK7

Machine: LOH Spheromatic

Cutting fluid:
Emulsion 3% (RatakMK),
2 nozzles, 3 and 4 l/min

Cup wheel: 2F2-40-3-6 / D25 / BZ335 / C25 (C40)

Cutting speed:
v_c = 20 m/s

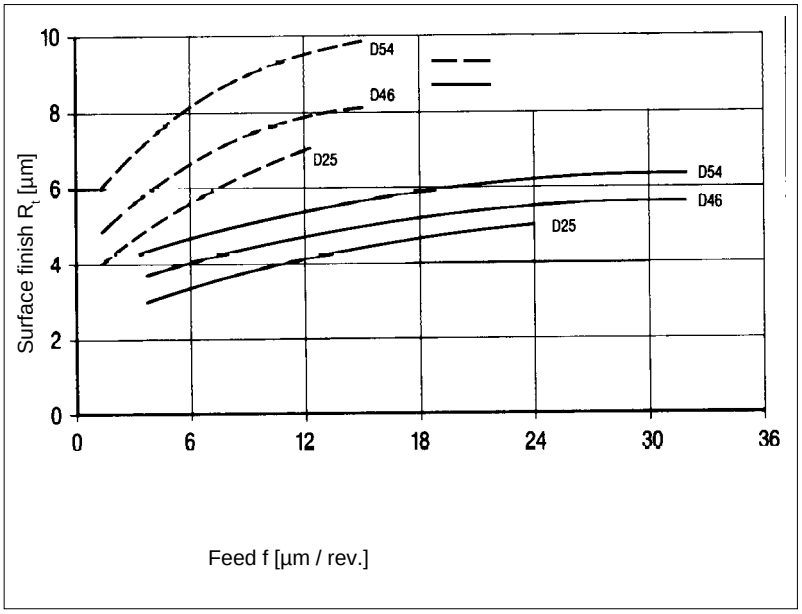
Spindle speed: n_s = 9950 rpm

Workpiece speeds:
n_w = 60 and 240 rpm

Fig. 1: Diamond concentration C25/C40 for different workpiece speeds n_w = 60 and 240 rpm and different feed rates f per revolution vs. surface finish R_t.

General technical notes

Test results for machining spherical surfaces,
IPT Fraunhofergesellschaft Aachen, Prof. König



Workpiece: Lens diameter 65 mm
Radius of curvature
R = 150 mm
Material BK7

Machine: LOH Spheromatic

Cutting fluid:
Emulsion 3% (RatakMK),
2 nozzles, 3 and 4 l/min

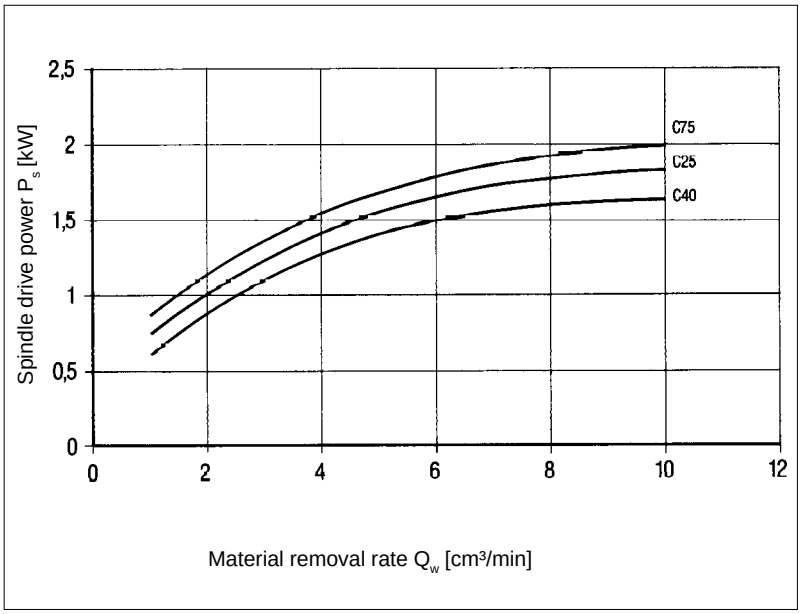
Cup wheel: 2F2-40-3-5-53-L4 /
D25 (D46 / D54) / BZ335 / C40

Cutting speed:
v_c = 50 m/s

Spindle speed: n_s = 23870 rpm

Workpiece speed:
n_w = 60 and 240 rpm

Fig. 2: Grit size D25/D46/D54 for different workpiece speeds n_w = 60 and 240 rpm, and different feeds f per revolution vs. surface finish R_t.



Workpiece: Lens diameter 65 mm
Radius of curvature
R = 150 mm
Material BK7

Machine: LOH Spheromatic

Cutting fluid:
Emulsion 3% (RatakMK),
2 nozzles, 3 and 4 l/min

Cup wheel: 2F2-40-4-5-53-L4 / D25 /
BZ335 / C40 (C25 / C75)

Cutting speed:
v_c = 50 m/s

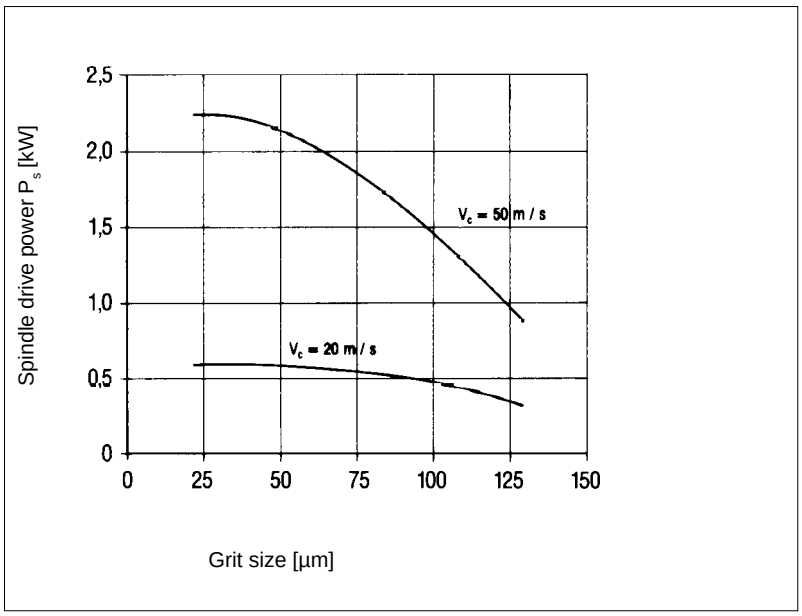
Spindle speed: n_s = 23870 rpm

Workpiece speeds:
n_w = 240 rpm

Fig. 3: Diamond concentration C25/C40/C75 for different material removal rates Q_w in cm³/min vs. required drive power P_s (kW).

General technical notes

Test results for machining spherical surfaces,
IPT Fraunhofergesellschaft Aachen, Prof. König



Workpiece: Lens diameter 65 mm
Radius of curvature
R = 150 mm
Material BK7

Machine: LOH Spheromatic

Cutting fluid:
Emulsion 3% (RatakMK),
2 nozzles, 3 and 4 l/min

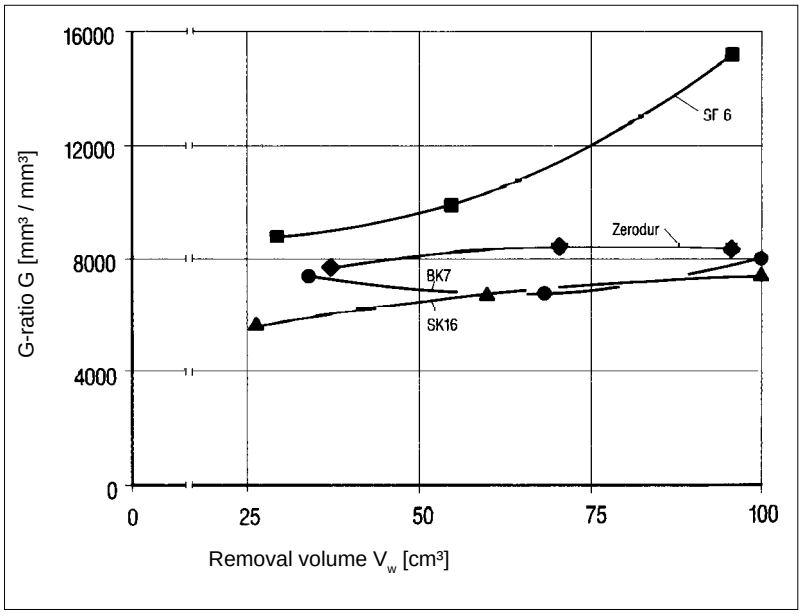
Cup wheel: 2F2-40-3-5-53-L4 /
D25 (D46 / D54) / BZ335 / C40

Cutting speed:
v_c = 50 and 20 m/s

Workpiece speeds:
n_s = 240 rpm

Material removal rate:
Q_w = 6.5 cm³/min

Fig. 4:Grit sizes D25 / D54 / D126 for different cutting speeds v_c = 50 and 20 m/s vs. required spindle drive power P_s (kW).



Workpiece: Lens diameter 65 mm
Radius of curvature
R = 150 mm
Material see diagram

Machine: LOH Spheromatic

Cutting fluid:
Emulsion 3% (RatakMK),
2 nozzles, 3 and 4 l/min

Cup wheel: 2F2-40-3-5-53-L4 / D46 /
BZ5474 / C40

Workpiece speed:
n_w = 180 rpm

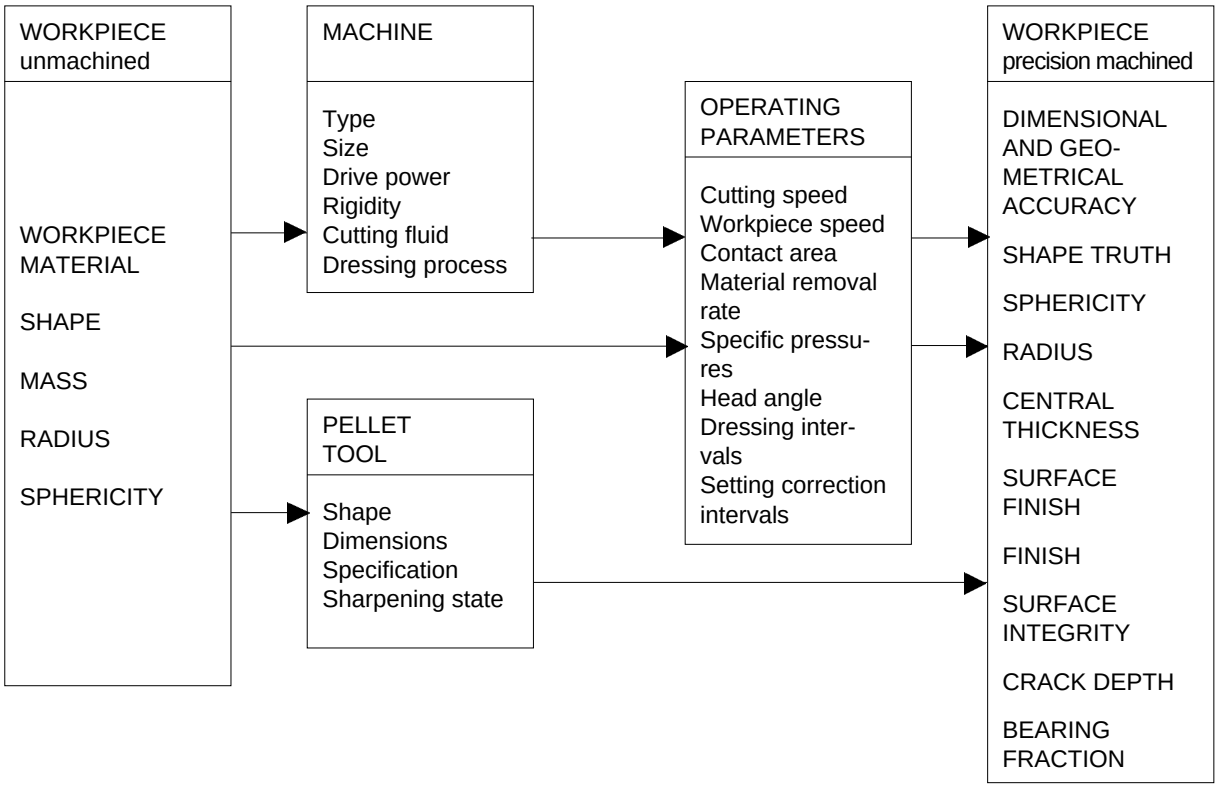
Infeed: f = 11 mm/rev

Dwell time
t_a = 0 s

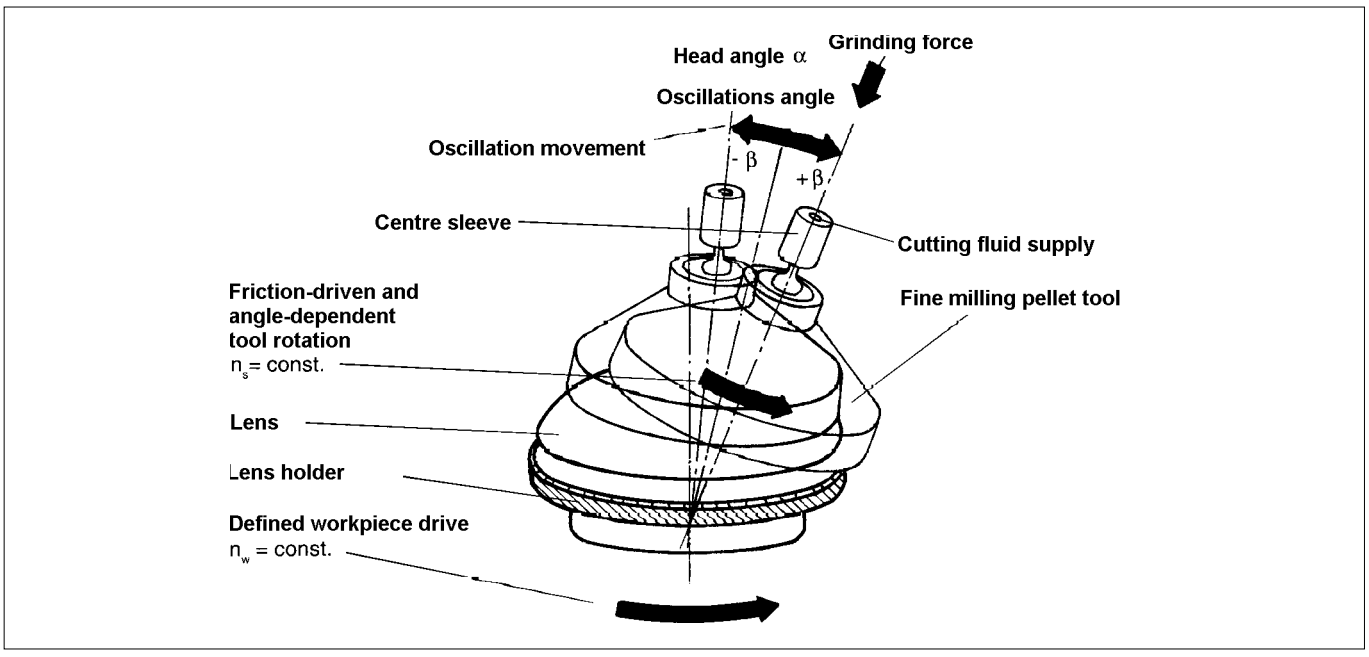
Fig. 5: G-ratio in mm³/mm³ for machining various glass materials.

General technical notes

Overview of ways to influence machining result for spherical surfaces.



Method for machining spherical lenses, IPT Fraunhofergesellschaft Aachen, Prof. König



General technical notes

Test results for fine milling of optical glass with pellet tools, acc. to IPT Fraunhofergesellschaft Aachen, Prof. König

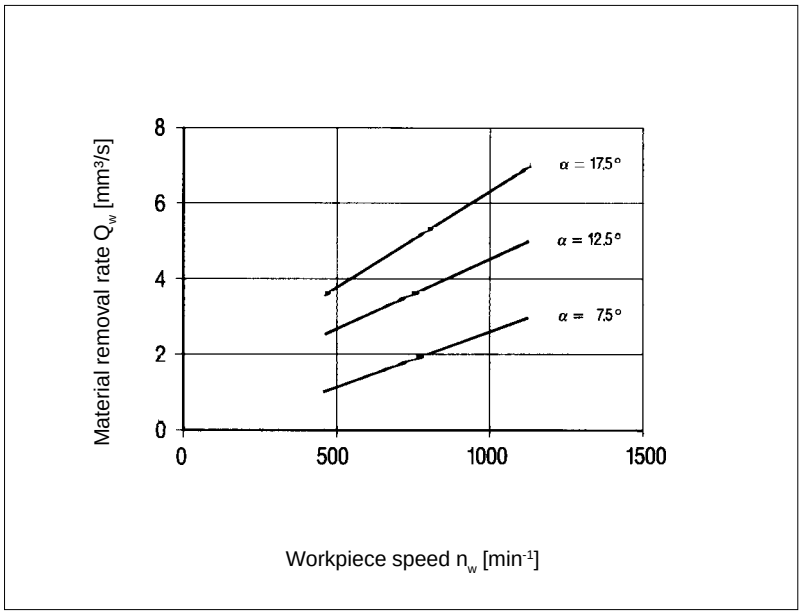
Test results

a) For precision milling of spherical surfaces

Fig. 1:	Material removal rate	Q_w	=	f	(workpiece speed n_w, head angle α)
Fig. 2:	Ave.peak-to-valley height	R_z	=	f	(workpiece material and pellet specification)
Fig. 3:	Ave.peak-to-valley height	R_z	=	f	(pellet specification)
	Shape constancy	$\Delta R:\Delta V_w$	=	f	(pellet specification)
	Material removal rate	Q_w	=	f	(pellet specification)
	Machining time	t_s	=	f	(pellet specification)
Fig. 4:	Ave.peak-to-valley height	R_z	=	f	(workpiece fracture behaviour, tool specification)
Fig. 5:	Ave.peak-to-valley height	R_z	=	f	(machining time t_s, diamond grit size)
Fig. 6:	Allowance	z	=	f	(machining time t_s, tool specification)
	Ave.peak-to-valley height	R_z	=	f	(allowance z, tool specification)
	Ave.peak-to-valley height	R_z	=	f	(machining time t_s,tool specification)
Fig. 7:	Ave.peak-to-valley height	R_z	=	f	(tool specification, initial surface finish R_{zo})
Fig. 8:	Shape constancy	$\Delta R:\Delta V_w$	=	f	(head angle α, workpiece speed n_w)

b) For fine milling of flat surfaces

Fig. 9:	Material removal rate	Q_w	=	f	(process time t_p)
Fig. 10:	Surface finish	R_t	=	f	(process time t_p)



Workpiece: Lens diameter 65 mm
R = 37.584 mm
Material SF57

Machine: LOH LP75

Tool: d_p = 8 mm

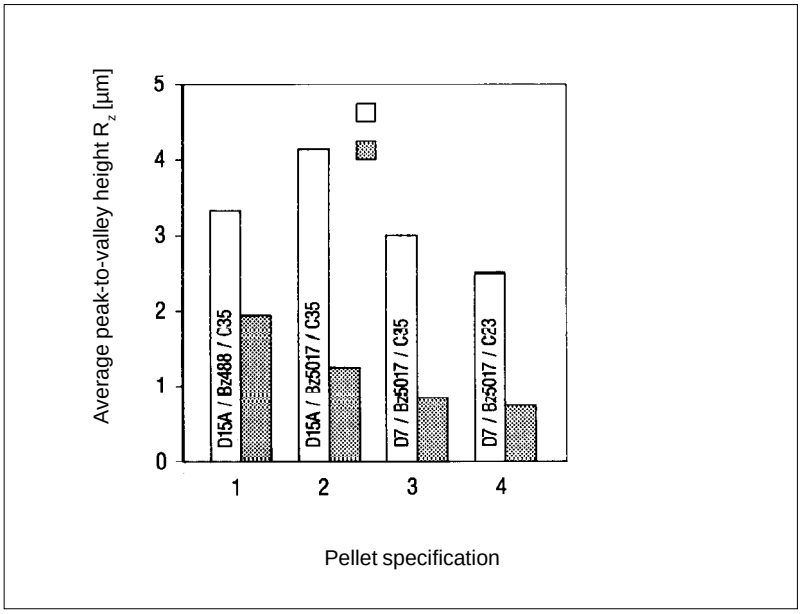
Specification: D15A / BZ5017 / C35
Grinding layer area
A_s = 1257 mm²

Parameter setting:
Head angle α =
7.5°-12.5°-17.5°
Oscillation angle β = +/- 5°
Main grinding force F_2 = 140 N

Fig. 1: Material removal rate Q_w can be increased as a function of workpiece speed and head angle.

General technical notes

Test results for fine milling of optical glass with pellet tools, acc. to IPT Fraunhofergesellschaft Aachen, Prof. König



Workpiece: Lens diameter 65 mm
R = 37.584 mm
Material SF57 and FK5

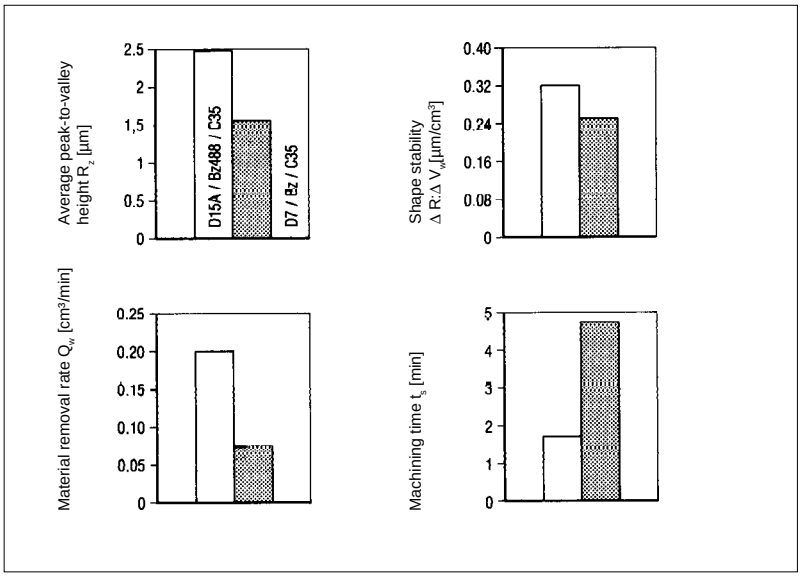
Machine: LOH LP75

Tool: d_p = 8 mm

Specification: 1 = D15A / BZ488 / C35
2 = D15A / BZ5017 / C35
3 = D7 / BZ5017 / C35
4 = D7 / BZ5017 / C23

Parameter setting:
Head angle α = 7.5°
Oscillation angle β = +/- 5°
Workpiece speed
n_w = 1000 rpm
Main grinding force F_2 = 140 N

Fig. 2: Average peak-to-valley height R_z is dependent on workpiece material and specification of pellet tool.



Workpiece: Lens diameter 65 mm
R = 37.584 mm
Material LaFN21

Machine: LOH LP75

Werkzeug: d_p = 8 mm

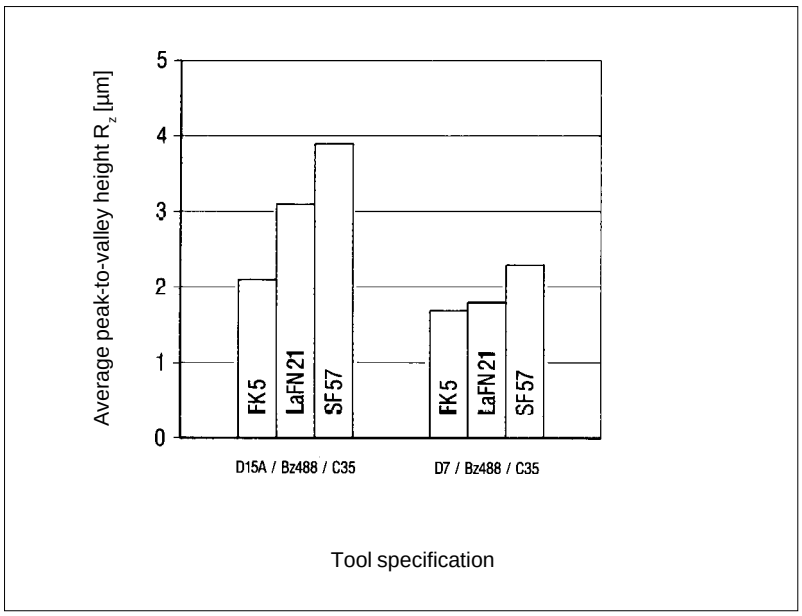
Specification: D15A / BZ488 / C35
D7 / BZ / C35
(soft bond)

Parameter setting:
Workpiece speed
n_w = 1000 rpm
Head angle α = 12.5°
Oscillation angle β = +/- 5°
Main grinding force
F_2 = 140 N (D15A)
F_2 = 233 N (D7)

Fig. 3: The influence of the harder bond BZ488 and the coarser grit size D15A show benefits in material removal rate Q_w and thus also in machining time t_s. The softer bond with the finer grit size D7 gives benefits in surface finish and shape stability $\Delta R:\Delta V_w$, without regard to the considerably higher main grinding force F_2, This advantage is at least 25%.

General technical notes

Test results for fine milling optical glass with pellet tools, acc. to IPT Fraunhofergesellschaft Aachen, Prof. König



Workpiece: Lens diameter 65 mm
R = 37.584 mm
Werkstoff FK5 / LaFN21 / SF57

Machine: LOH LP75

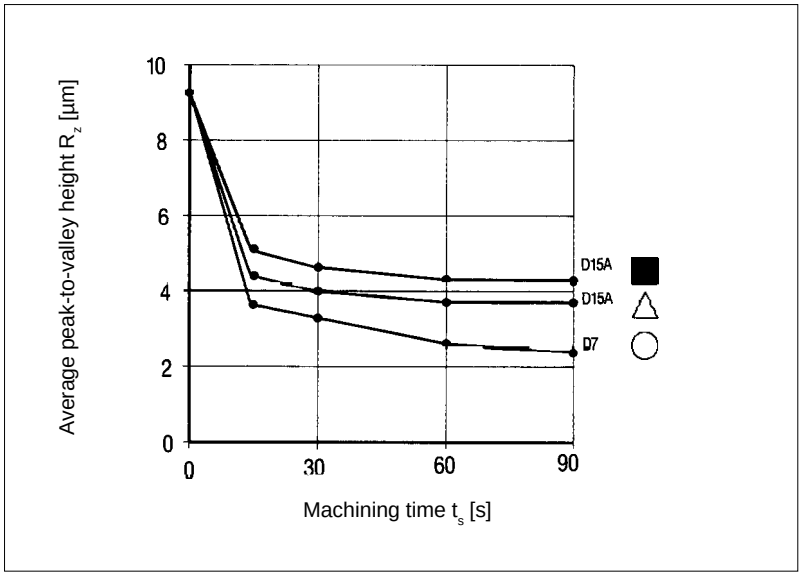
Tool: d_p = 8 mm

Specification: Grinding layer area
A_s = 1257 mm²
D15A and D7 / BZ488 / C35

Parameter setting:
Head angle α = 12,5°
Oscillation angle β = +/- 5°
Workpiece speed
n_w = 1000 rpm
Machining time t_s = 60 s
Main grinding force F_2 = 140 N

Fig. 4: The attainable surface finishes are an indication for the fracture behaviour of the material. As might be expected, D15A gives rougher surface finish for all materials than does the D7 grinding layer. The trend shows that the surface finish after rough machining is an indicator for achievable surface topography after fine milling.

SF57 appears to be a particularly crack-sensitive glass, where surface finish can hardly be reduced below the 2 µm limit. FK5 permits surface finishes of less than 2 µm with D15A pellets, i.e. finer grits are mostly more cost-effective. LaFN21 has a medium position, despite the favourable R_z values for D7. With this glass, the deep crack systems should not be underestimated.



Workpiece: Lens diameter 65 mm
R = 37.584 mm
Material SF57

Machine: LOH LP75

Tool: d_p = 8 mm

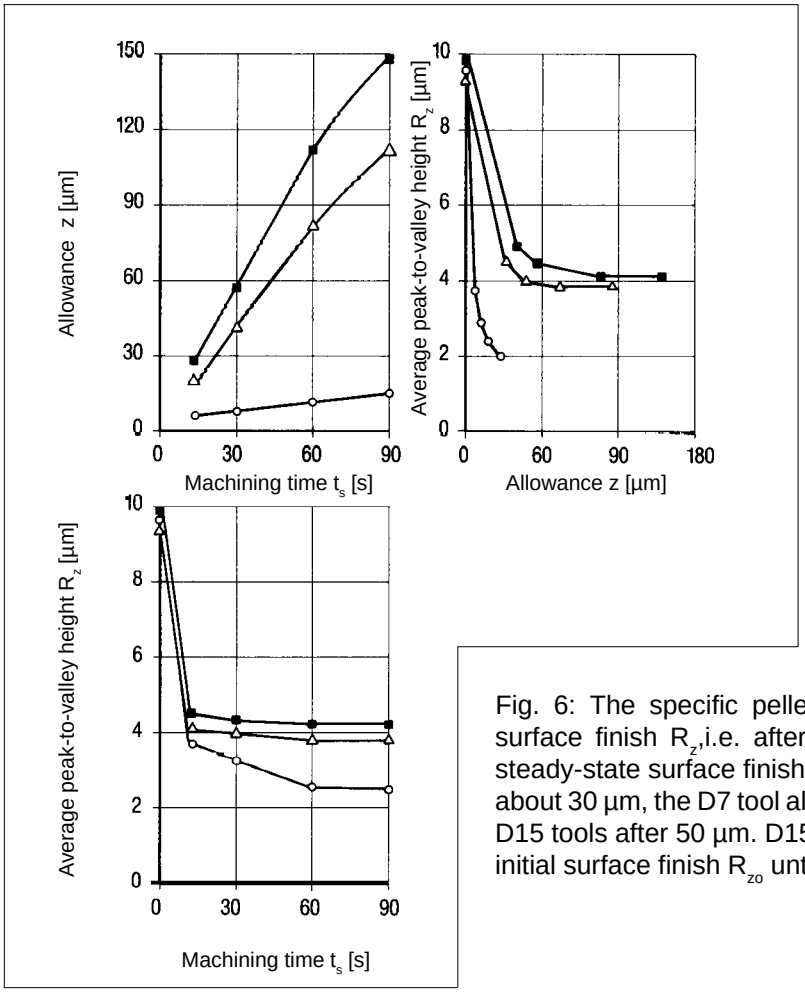
Specification: Grinding layer area 1257 mm²
D15A / BZ488 / C35 ■
D15A / BZ5017 / C35 △
D7 / BZ 5017 / C35 ○

Parameter setting:
Workpiece speed
n_w = 1000 rpm
Head angle α = 12,5°
Oscillation angle β = +/- 5°
Main grinding force F_2 = 140 N

Fig. 5: Diamond grit size, not machining time, determines the attainable workpiece surface finish R_z.

General technical notes

Test results for fine milling optical glass with pellet tools, acc. to IPT Fraunhofergesellschaft Aachen, Prof. König


Allowance z [µm]
Machining time t_s [s]
Average peak-to-valley height R_z [µm]
Allowance z [µm]
Average peak-to-valley height R_z [µm]
Machining time t_s [s]

Workpiece: Lens diameter 65 mm
R = 37.584 mm
Material SF57
Initial surface finish R_{zo} = 9µm

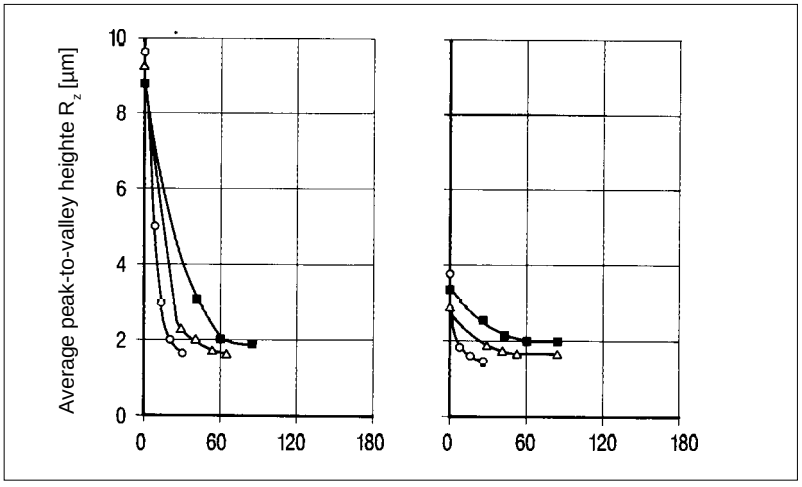
Machine: LOH LP75

Tool: d_p = 8 mm

Specification: D15A / BZ488 / C35 ■
D15A / BZ5017 / C35 △
D7 / BZ5017 / C23 ○

Parameter setting:
Head angle α = 12.5°
Oscillation angle β = +/- 5°
Workpiece speed
n_w = 1000 rpm
Main grinding force F_2 = 140 N

Fig. 6: The specific pellet specification determines the attainable final surface finish R_z,i.e. after sufficient allowance Z has been removed, a steady-state surface finish R_z is achieved. After a material removal of only about 30 µm, the D7 tool already has an R_z value that is 50% lower than the D15 tools after 50 µm. D15 tools have to remove 10 times the value of the initial surface finish R_{zo} until the surface finish R_z remains constant.



Workpiece: Lens diameter 65 mm
R = 37.584 mm
Material SF57
Initial surface finish R_{zo} = 9µm

Machine: LOH LP75

Tool: d_p = 8 mm

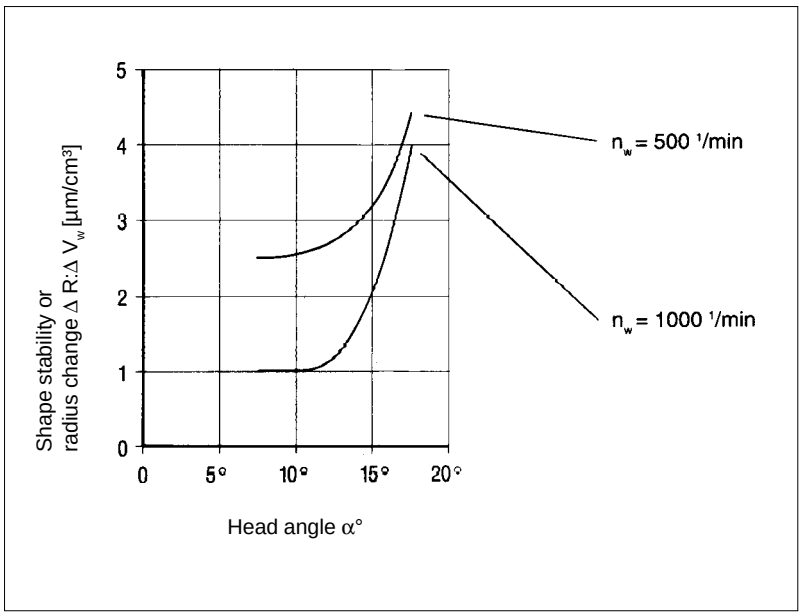
Specification: D15A / BZ488 / C35 ■
D15A / BZ5017 / C35 △
D7 / BZ5017 / C25 ○

Parameter setting:
Head angle α = 12.5°
Oscillation angle β = +/- 5°
Workpiece speed
n_w = 1000 rpm
Main grinding force F_2 = 140 N

Fig. 7: The average peak-to-valley height R_z is virtually independent of workpiece specification.

Test results for fine milling glass with pellet tools, acc. to IPT Fraunhofergesellschaft Aachen, Prof. König

General technical notes



Workpiece: Lens diameter 65 mm
R = 37.584 mm
Material SF57
Initial surface finish R_{zo} = 7 µm

Machine: LOH LP75

Tool: d_p = 8 mm

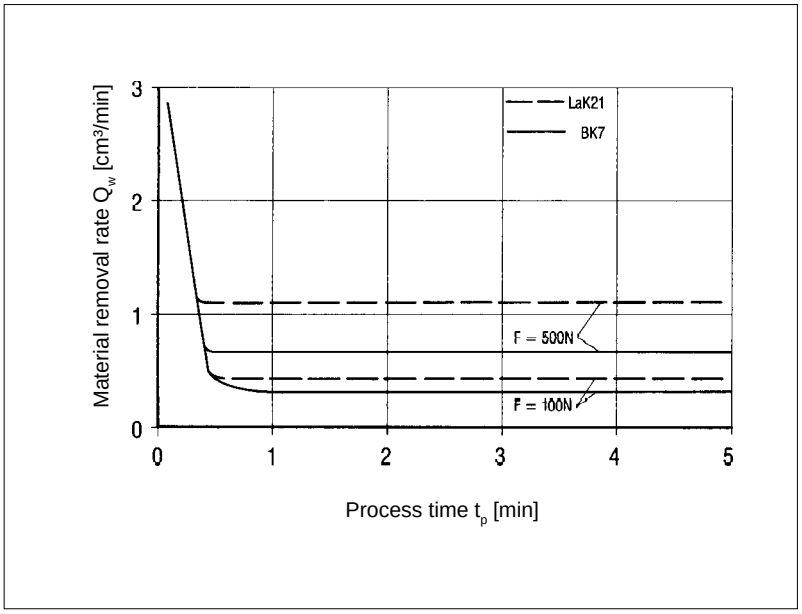
Specification: Grinding layer area
A_s = 1257 mm²
D15A / BZ5017 / C35

Parameter setting:
Head angle α = 7.5°...17.5°
Oscillation angle β = +/- 5°
Workpiece speed
n_w = 500 and 1000 rpm
Machining time t_s = 60 s
Main grinding force F_2 = 140 N

Fig. 8: Shape constancy is influenced in particulary by the head angle, i.e. the smallest radius variation value is achieved at α = 7.5°. The workpiece speed n_w has practically no influence. R_o = 37.585 - 37.588 mm.

General technical notes

Test results for fine surface milling with pellet tools, acc. to Thesis by Klasmeier



Workpiece: Flat lens holder
Diameter 225 mm
fitted with 12 flat lenses
BK7, LaK21, d_L = 55 mm

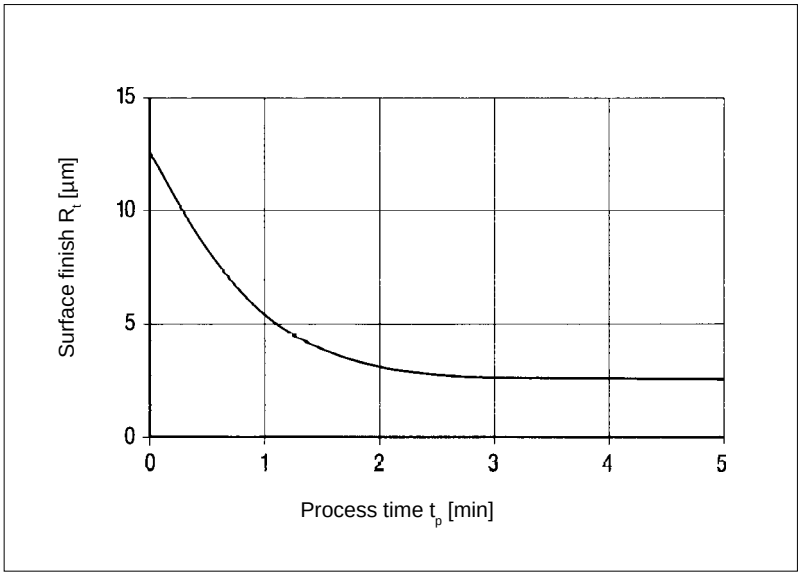
Machine: LOH PLM 400
n_w = 120 rpm
n_o = 115...125 rpm

Tool: Pellet tool
Diameter = 300 mm
fitted with 60 pellets 10 x 3 mm
D15A / BZ488 / C35

Cutting fluid:
AC4076, 0.45 l/min, 1.45 bar

Contact pressure:
F = 100 N

Fig. 9: The material removal rate Q_w is not dependent on the contact pressure F or on the machining time t_p. The material removal rate approximates to a virtually steady-state value within the first minute.



Workpiece: Flat lens holder
Diameter 225 mm
fitted with 12 lenses
BK7, d_L = 55 mm

Machine: LOH PLM 400
n_w = 120 rpm
n_o = 115...125 rpm

Tool: Pellet tool
Diameter = 300 mm
fitted with 60 pellets 10 x 3 mm
D15A / BZ488 / C35

Cutting fluid:
AC4076, 0.45 l/min, 1.45 bar

Contact pressure:
F = 100 N

Fig. 10: Surface finish R_t is dependent on the process time t_p, but approaches a virtually steady-state value.

Recommended reading

König, Meis: Entwicklungsmöglichkeiten in der Bearbeitungstechnologie sphärischer optischer Gläser, IDR 14 (1980), Nr. 4, Seite 202.

Juranek: Realisierungsmöglichkeiten in der Bearbeitung optischer Bauteile mit Diamantwerkzeugen, IDR 16 (1982) Nr. 4, Seite 225.

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NN: Schott-Lexikon der Optik, Schott-Glaswerke, Mainz.

König, Steffens, Kleinevoß, Pahl: Auswahl von Diamantwerkzeugen für die Bearbeitung optischer Gläser, Technische Mitteilungen, 80. Jahrgang, Heft 1/87, Seite 17-21, Verlag HAUS DER TECHNIK, Essen.

WINTER MANUFACTURING PROGRAMME

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	Diamond pellets and pads for the optical industry Diamond grinding wheels for the optical industry, flat glass, crystal glass, ceramics and semi-conductor machining
	CBN grinding wheels CBN grinding pins
Files	Diamond files for hand and machine use
Sawing	Diamond and CBN sawblades -continuous rim and segmented cutting edge- Diamond bandsaws and wire saws Diamond ID sawblades
Honing	Diamond and CBN honing tools
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Polishing	WINTER-Diaplast® WINTER-Diaplast®-suspension Diamond and CBN micron powders
Other	Diamond grit Unprocessed diamonds Dressing units and sharpening sticks
Inquiries to:	SAINT-GOBAIN Diamantwerkzeuge GmbH & Co. KG Schützenwall 13-17, D-22844 Norderstedt, Tel. +49 40/5258-0, Fax +49 40/5258-381
	Stuttgart office: SAINT-GOBAIN Diamantwerkzeuge GmbH & Co. KG POB 30 12 69, D-70452 Stuttgart, Tel. +49 711/81009-0, Fax +49 711/8100940

	Repair of mounted diamond dressers and ground profile diamonds
Inquiries to:	SAINT-GOBAIN Diamantwerkzeuge GmbH & Co. KG Am Redder 1, 22941 Bargteheide, Telefon: +49 (0) 4532 40 40-0, Fax: +49 (0) 4532 40 40-65

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DIN EN ISO 14001
Certifcate No.
EM-2129 HH

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Certifcate No.
QS-453 HH

Organisation für
die Sicherheit von
Schleifwerkzeugen e.V.

LG-Nr. 16 /02 e